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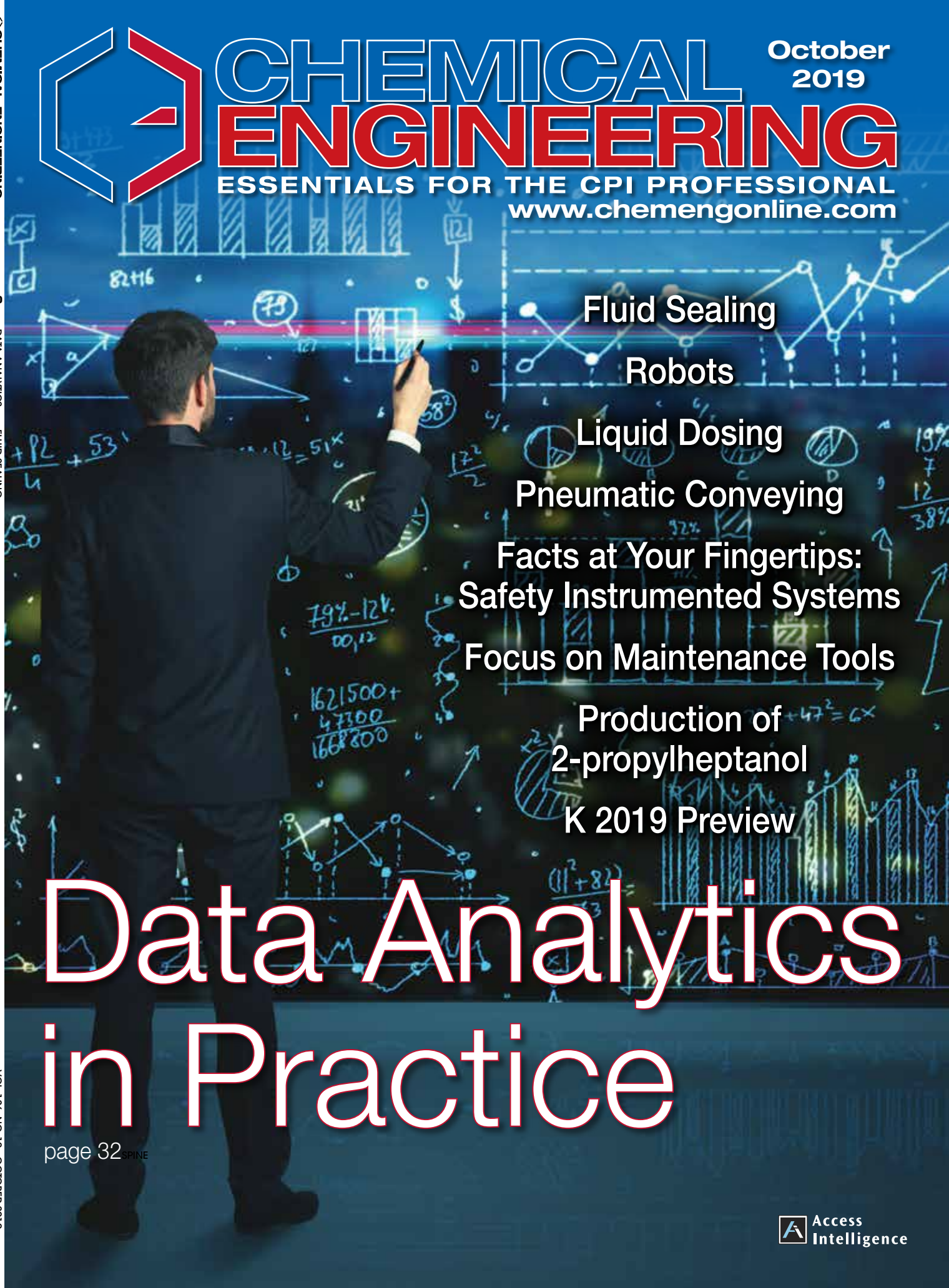

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Robots

Liquid Dosing

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Focus on Maintenance Tools

Production of 2-propylheptanol

K 2019 Preview

Data Analytics in Practice

page 32 SPINE

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October 2019 Volume 126 | no. 10

Cover Story

32

In the News

16

20

45

Technical and Practical

51

56

24

26

Equipment and Services

Departments

Advertisers

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Editor's Page

Advances in data analytics and robots

It seems that not all that long ago, terms like "smart" sensors and wireless communication were making headlines in industrial technology. Those technologies have now become part of the foundation for what, in recent years, has been a rapid growth of advances that include the concepts of data analytics, machine learning, artificial intelligence, digital twins, virtual reality, robotics and much more. While some early-adopter industrial facilities are broadly implementing these technologies, many others — perhaps most others — are grappling with how to navigate the complex web of available technologies and best utilize the reams of data that have become available.

Data analytics

One of the comments that I have often heard is that while much process data can now be readily collected, plant personnel don't have the resources to sift through and use it. Detailed analyses of data can undoubtedly help plant operations, such as in streamlining maintenance and optimizing processes. A recent report by Lloyd's Register (www.lr.org: "Oil and Gas: Achieving operational excellence in uncertain times"), based on a survey of 100 asset managers in the oil-and-gas industry, states that although predictive maintenance can lead to cost savings of 10–40%, only 18% of companies are using this approach. The report cites a reluctance to implement advanced maintenance strategies due to "perceived difficulties," namely the investments needed in both the technologies and in skilled professionals.

Our two-part cover story (pp. 32–44) explains how data analytics is becoming easier for engineers to implement, without the need for data analyst experts. The articles offer examples of how data analytics has been successfully applied in the chemical process industries (CPI).

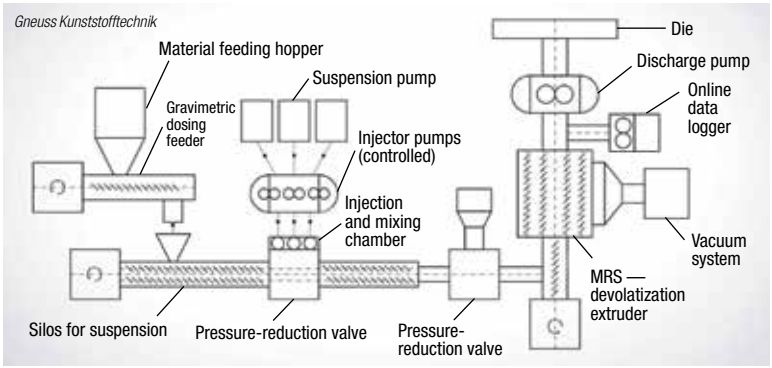
Robotics

While robots have been around for quite some time, current robotic technologies have become much more sophisticated and are finding new applications. In the CPI, robots are helping, but not replacing workers, to carry out both monotonous and dangerous tasks. This month's Newsfront (pp. 16–19) explores some of the latest applications where robots are being used to increase efficiency and safety.

There is, however, concern among many that robots will take away jobs. The effect of automation on the workplace, and in a broader sense on society, is the subject of an interim report issued last month by a task force from the Massachusetts Institute of Technology (MIT; www.mit.edu). The report, "The Work of the Future: Shaping Technology and Institutions," offers insight on several complex issues, including the growth of higher- and lower-skill jobs, but a loss of middle-skill jobs. The report states that "Technological advances did deliver productivity growth over the last four decades, but productivity growth did not translate into shared prosperity." The impact that automation has on our workforce depends not just on the technology, but on policies and more. "Technology is a human product," said David Mindell, co-chair of the task force, professor of aeronautics and astronautics at MIT. "We shape technological change through our choices of investments, incentives, cultural values, and political objectives." The task force plans to continue its work and issue a final report next year with the goal of bringing a holistic perspective on technology and the labor market. ■

Dorothy Lozowski, Editorial Director

Incorporating nanoparticles into polymer melts



Because of their large surface area per unit mass, nanoparticles of additives can have a big impact on the properties of plastics, such as changing the crystallization temperature, and improving heat transfer, electrical properties (conductivity) and mechanical properties, as well as improving surface finish and brilliance and antibacterial properties. Although the incorporation of nanoscale fillers into polymer melts is an established technology, the process can be problematic due to the formation of agglomerates.

Now, after six years of development work, Gneuss Kunststofftechnik GmbH (Bad Oeynhausen, Germany; www.gneuss.com) offers an industrial-scale process that enables the introduction of individual nanoparticles (from 1 to 1,000 nm) into polymers, without the formation of agglomerates. This is done by means of a liquid suspension, which not only prevents agglomeration, but also prevents the release of potentially hazardous particles into the environment.

In the process (diagram) the polymer is first plasticized, then flows through a mixing and hydrolysis chamber, where a suspension is injected under pressure into the polymer. The mixture of polymer and suspension flows into a devolatilizing extruder that Gneuss developed for this process. With a mixture of polymer (>70%) and suspension (<30%), the suspension carrier is removed within less than 5 s. In such a short time, the nanoparticles are completely embedded in the polymer, and there is practically no damage to the polymer, says the company.

With the Gneuss Nano Compounding Technology, it is possible to achieve the same material properties with a major reduction in the quantity of additive needed, says the company. In many cases, the desired properties are achieved with such a small quantity of additive, that unwanted side effects are negligible. For example, a polymer can be made conductive by adding carbon nanotubes, without the need for the polymer to be completely black.

Collaborative wastewater project points the way to improved phosphorus removal

Removal of phosphorus and other nutrients from wastewater is critical to preventing harmful algal blooms in coastal waters. Enhanced biological phosphorus removal (EBPR) — which relies on microbial communities that consume phosphate, reducing its concentration in the wastewater — has been used for decades, but the microbial ecology and optimal design of the systems are not fully understood.

Now, a large collaborative research project led by Black & Veatch (Overland Park, Kan.; www.bv.com) and funded in part by the Water Research Foundation (WRF; Alexandria, Va.; www.waterrf.org), is developing guidelines for municipal wastewater treatment plants for using side-stream EBPR, a set of configurations for biological phosphorus removal that aims to increase the stability of the treatment system against variations in the influent water, as well as to lower costs.

"In side-stream EBPR, a portion of the wastewater biomass enters a side fermentation tank where bacterial communities are selected for the fermentative conditions that are best for phosphate removal," says Leon Downing, Black & Veatch engineer and principal investigator of the research project. And those microbe communities are introduced back into the treatment system to lower the phosphorus concentration. "By looking at different arrangements of wastewater treatment assets, and different fermentation conditions, we are making progress in understanding how to optimize the EBPR process and make it easier for municipalities to implement the technology to improve the stability of phosphorus removal and lower costs," Downing says.

The 2.5-yr project involves five consulting firms, 5 universities and 19 water utility partners in the U.S. and Canada.

Edited by:
Gerald Ondrey

CARBYNE TRANSFER

Marcos G. Suero and his research group at the Institute of Chemical Research of Catalonia (ICIQ; Tarragona, Spain; www.iciq.es) have reported a new reaction that inserts a monovalent carbon unit between both sp^2-hybridized carbons of alkenes. For the reaction, the chemists developed a first catalytic generation of rhodium-carbynoids, which emulate the carbene/carbocation behavior of a monovalent cationic carbyne. The catalytic generation of Rh-carbynoids represents a new platform for carbyne transfer that enables skeletal remodeling, and circumvents a long-standing challenge in the catalytic generation of metal-carbynes.

Aside from inserting a new monovalent carbon atom, the reaction also introduces extra complexity in the molecule: a single C–C bond and a double C–C bond are created together with a chiral center at one of the C atoms with the cleaved double bond. The skeletal editing will allow building complex architectures, thus expanding the synthetic possibilities of creating new materials or medicines. The findings are described in the September 12 issue of the *J. Am. Chem. Soc.*

APPAREL FROM PET

Last month, Toray Industries, Inc. (Tokyo, Japan; www.toray.com) launched a new commercial brand of fibers, called &+, which are derived from used polyethylene terephthalate (PET) bottles. The company is aiming to leverage this brand to foster PET bottle recycling and to help materialize a closed-loop economy.

Fashion items, sportswear, lifestyle wear, work uniforms and consumer goods are among the applications

(Continues on p. 8)

that have been effectively off-limits to plastic-bottle-derived fibers because of contaminants in the waste. Another issue has been that the plastic bottles yellow as they age, impairing efforts to create white fibers.

Toray developed techniques to manufacture an array of high-value-added, exceptionally white plastic bottle-derived fibers that incorporate traceability technology. Together with Kyoei Industry Co., Toray developed contaminant-filtering technology and advanced cleaning techniques to stabilize the supply of raw materials that are impurity-free and no longer yellowish when used in textile and garments applications. Combining these materials with Toray's fiber-production technology, it is possible to achieve diverse fabric applications and perfect dye-ability comparable to the fiber materials made directly from a petroleum source. The company's proprietary Recycling Identification System detects special additives premixed in the raw materials, enabling traceability.

RECYCLING LIBS

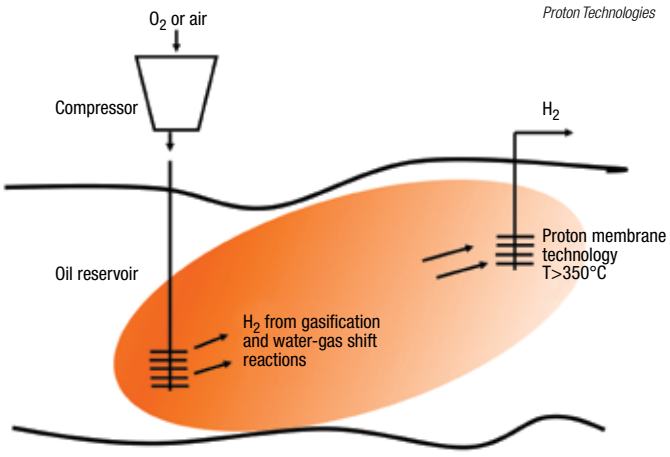
Last month, a new project was started to develop a closed-loop process for recycling lithium-ion batteries (LIBs). The Recycling Li-ion batteries for electric Vehicle (ReLieVe) project — led by Eramet (Paris, France; www.eramet.com), BASF SE (Ludwigshafen, Germany; www.basf.com) and SUEZ (Paris, France; www.suez.com) — will receive €4.7 million from the E.U. and the three partners to develop the process and to structure a well-integrated recycling industry.

The project will officially start in January 2020 and run for two years. The project ReLieVe will carry out a series of activities for the large-scale development of the recycling process and the structuring of an inte-

(Continues on p. 10)

Underground oxidation of hydrocarbons and gas separation yields hydrogen

A process for in-situ oxidation of hydrocarbons in low-quality oilfields, and subsequent gas separation, offers a path to generating hydrogen for fuel and chemicals that avoids any greenhouse gas emissions. Known as Hygienic Earth Energy (HEE), the process has been demonstrated at small scale in the western Canada oil sands, and the developing company, Proton Technologies Inc. (Calgary, Alberta; www.proton.energy), is working to scale up the technology in the coming months.



Proton Technologies

The process works by first injecting oxygen-enhanced air into an underground hydrocarbon reservoir, which would typically be a depleted, late-life or marginally productive oil play. The oxidation processes are initiated by raising the temperature in certain areas of reservoir using steam or other means, but then the reactions continue spontaneously as long as O_2 is present within the pore network of the geological substrate that contains the hydrocarbons (sand grains in the case of oil sands).

"Several different oxidation processes are occurring simultaneously underground," explains Brian Harschnitz, advisor to Proton Technologies. "But the ones that are the most important for hydrogen production are gasification and the water-gas shift reaction." As the in-situ oxidation occurs, the H_2 is separated from the mixed-gas products and piped toward the surface (diagram). The H_2 is separated using a membrane of palladium-copper alloy, which allows only the H_2 into the wellbore. The membrane is similar to those used in steam-methane reforming, Harschnitz says.

A concentration gradient is established across the membrane, where the multiple-gas side reaches about 4 MPa of pressure, while the surface remains at atmospheric pressure. H_2 gas can dissolve in the Pd metal, and moves through the membrane from the high-pressure side to the low-pressure side, while other gases, including CO_2, remain sealed underground.

Many elements of the process, including the control of in-situ oxidation and the operation of the gas-separation membrane, are well understood, Harschnitz says, "so it is more a matter of putting it all together." Because the reactions are occurring underground, there is no need for built reactors on the surface, so the cost structure is lower, he adds. "We are generating a carbon-free fuel from residual oil that has very little value otherwise."

Reducing CO_2 to methane

Electrochemical reduction of carbon dioxide to hydrocarbons and oxygenates on copper involves reduction to a carbon monoxide adsorbate followed by transformation to hydrocarbons and oxygenates. To ensure the sustainability of the process, the electrochemical CO_2 reduction is typically conducted in an aqueous electrolyte, where the protons required are obtained. To convert CO_2 into fuels, you have to start with a surface made of copper. However, this process requires two reactors and costly separation and purification steps.

A new approach has been reported by a team of researchers from the University of Delaware (Newark, Del.; www.udel.edu), Columbia University (New York, www.columbia.edu), California Institute of Technology (Pasadena; www.caltech.edu), Tsinghua University (Beijing, China; www.tsinghua.edu.cn) and National Cheng Kung University (Tainan, Taiwan; www.ncku.edu.tw). The team utilizes a series of catalytic reactions to electrochemically reduce CO_2 to methane, eliminating an intermediate step usually required in the reduction process. The team developed a one-pot catalysis system by adding special nanostructured silver surfaces to the copper surfaces. By constructing a well-defined copper-modified silver surface, adsorbed CO generated on the silver sites migrates to surface copper sites for the reduction to methane. The system yields a higher concentration of methane than copper-only systems.

The team systematically modified the silver-to-copper ratio in the structure, which is the key to the selectivity and ability to combine the reactions.

grated industrial sector from the collection and dismantling of end-of-life batteries going into recycling all the way to the manufacturing of new electrode materials.

SUEZ will focus on collection and dismantling of end-of-life batteries; Eramet on the development of the recycling process; and BASF on the manufacturing of cathode-active materials. Academic researchers from Chimie ParisTech and the Norwegian University of Science and Technology will support the members to accelerate the search for innovative solutions. The industrial members will also be backed by the automotive sector, which will be part of the advisory committee.

"Around 50,000 tons of batteries are expected to be recycled by 2027 in Europe and it could be multiplied almost tenfold by 2035. With the ReLieVe project, SUEZ is supporting the development of alternatives approaches that blend circular solutions with sustainable urban mobility," says Jean-Marc Boursier, SUEZ COO.

SORTING PLASTICS

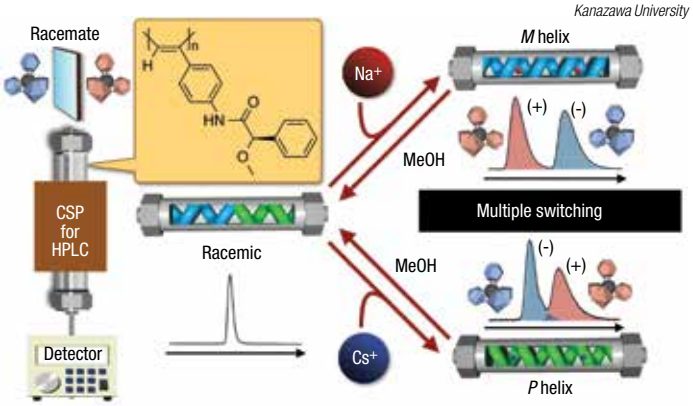
Near-infrared (NIR) sensors can discriminate between high-density polyethylene (HDPE), low-density PE, polypropylene (PP), polyester and various other commonly used polymers in today's packaging. However, the carbon-black pigments typically used to make black plastics absorb all or most of the NIR light shone at them. As a result, the sorting sensors cannot even "see" the black packaging, much less sort one polymer from another.

"As a result of this phenomenon, much of the dark-colored materials entering the recycling

(Continues on p. 11)

Multi-state switchable stationary phase for chiral separation

Kanazawa University



High-pressure liquid chromatography (HPLC) using a chiral stationary phase (CSP) is the most effective method for separating enantiomers of chiral molecules. However, the limited number of CSPs available puts a constraint on applying this technology universally. Now, researchers from the group of Katsuhiro Maeda at Kanazawa University (Kanazawa City, http://kohka.ch.t.kanazawa-u.ac.jp), in collaboration with the University of Santiago de Compostela, have demonstrated enantiomeric separations using HPLC with an optically active poly(phenylacetylene) derivative as the CSP. The helical conformation of the polymer can be controlled through changing the mixed state of left- or right-handed chiral conformations by introducing Na^+ or Cs^+ ions, respectively. This results in a switchable system that offers three different modes of recognition.

The switchable CSP is based on a helical polymer material (diagram) containing a chiral pendant group that causes the polymer to adopt different conformations in response to metal ions. When Na^+ ions are present, the polymer is forced to adopt a left-handed helix so that the ions can interact with the aromatic component of the group. In contrast, when Cs^+ ions are present, the polymer is forced into a right-handed helix to facilitate bonding between the ions and the two oxygen atoms of the group. The effect can be reversed by eluting the column with methanol. In the absence of ions, the structure is a deactivated mixture of the two helices.

The researchers showed the stability of the ion-induced states after more than four days of continuous flow through the column, and exhibited the separation performance by switching between the active and deactivated state numerous times.

Ionic liquids enable lower-cost desalination with forward osmosis

Membrane-based forward osmosis (FO) desalination could be a lower-cost alternative to conventional reverse osmosis (RO) technology, which can desalinate ocean water effectively, but requires electricity to drive the separation, and so remains expensive. Scientists from Lawrence Berkeley National Laboratory (LBL; Berkeley, Calif.; www.lbl.gov) have developed an FO technology that addresses its inherent challenges, potentially lowering desalination energy costs.

In FO desalination, the osmotic pressure gradient between a concentrated "draw" solution and a feed solution from which salt is to be removed drives water passively across a semi-permeable membrane (in RO, the salty feedwater is pumped against the gradient). Making FO viable requires a draw solution with enough osmotic potential to drive the salt/water separation, but that also allows easy and low-energy regeneration to separate the purified water from the salty draw solution. In engineering the draw solution, the LBL team used ionic liquids (ILs) from a class that is thermally responsive, and developed candidates with a unique property: a lower critical solution temperature (LCST).

Facility director at LBL's Molecular Foundry Jeff Urban explains: "Ordinary liquid mixtures become more miscible as temperature is increased ... However, for ILs that have an LCST, the opposite is true: they separate with increased temperature. This means that ILs can be used as good draw solutions at low temperatures — pulling in water and making a miscible mixture, and then that water can be pulled out and the ILs recycled just by increasing the temperature." The thermal response of the ILs allows them to be regenerated with industrial low-grade waste heat, reducing cost.

The LBL team's research uncovered new information about the behavior of ILs — namely that their ability to separate water molecules from seawater depends on the proximity of its organic components to their positively charged ions, not on the overall ratio of organic to ionic components. Urban and study co-leader Robert Kostecki say the insight will help in the design of ILs for next-generation FO process now under development.

Engineered microbes convert C1 feedstocks into longer-chain chemicals

Researchers at the University of South Florida (USF; Tampa, Fla.; www.usf.edu) have developed a microbial metabolic pathway that allows enzymatic conversion of one-carbon compounds into multi-carbon intermediate chemicals. The bioconversion process, which takes place in genetically engineered bacteria, could enable a host of industrially relevant processes involving the bioconversion of C1 compounds to other chemicals. These include utilizing methane that is typically flared in oil and gas operations, and converting formate from the electrochemical reduction of CO_2 into ethylene glycol.

Using metabolic engineering techniques, the USF researchers were able to insert genes for a prokaryote analog of the human enzyme 2-hydroxyacyl-coenzyme A lyase (HACL) into *Escherichia coli* bacteria and engineered a variant that improves activity. Normally, HACL enzymes break down long-chain fatty acids into smaller molecules, but the USF team was able to engineer the system so that the enzyme worked on the reverse reaction, with microbes consuming C1 compounds and forming new carbon-carbon bonds to build multi-carbon molecules.

To demonstrate the metabolic pathway, the USF team reported engineered microbes capable of converting formaldehyde into ethylene glycol, glycolic acid and others. USF professor of chemical engineering Ramon Gonzalez says the researchers are also working on systems for converting more oxidized C1 compounds, such as CO_2, and more reduced C1s, such as methanol and methane. In the case of methane, the team published a paper describing the engineering of the C–C-bond-forming metabolic pathway into methanotrophs (bacteria that utilize methane).

"Methane is often found with petroleum deposits, and it is typically flared due to the unfavorable economics of capturing and transporting it," Gonzalez explains. "To utilize the associated methane, an approach that is economical at smaller scales is needed, and biotechnology can often surpass conventional chemistry in these cases," because fermentation-based processes require lower capital expenses and can be deployed in more distributed locations.

stream has not been recovered," explains Alessandro Dulli, global head of packaging at Clariant Masterbatches (Muttenz, Switzerland; www.clariant.com). "For that reason, many brand owners have been pressured to move away from black for environmental reasons," says Dulli.

Clariant has developed CESA-IR additive masterbatches to make dark-colored plastics visible by NIR. Specific CESA-IR formulations have been developed for black HDPE and LDPE in injection and extrusion blow-molded products; black PP in films and injection-molded products; and black PET and C-PET in sheets and film. ❑

Making solar steam and salts from brine

A low-cost "green" technology for water desalination and zero liquid discharge of industrial wastewater that has been drawing increasing attention is solar steam generation using nanostructured photothermal materials. However, the crystallization of salts on the surface of photothermal materials during steam generation leads to a gradual decline in the water evaporation rate.

Researchers from Monash University (Melbourne, Australia; www.monash.edu) have overcome those challenges by developing a solar steam-generation system that achieves efficient and continuous clean water production from salty water with nearly 100% salt removal. Their design involves controlled water transport, which controls salt crystallization only at the edge of the evaporation disc, and gravity-assisted salt harvesting.

The researchers created a disc using super-hydrophilic filter paper with a layer of carbon nanotubes for light absorption. A cotton thread (1-mm dia.) acts as the water transport channel, pumping saline water to the evaporation disc. The saline water is carried up by the cotton thread from the bulk solution to the center of the evaporation disc. The filter paper traps the pure water and the remaining salt collects on the edges of the disc. The disc exhibits a rapid temperature increase when exposed to light in both dry and wet states, rising from 25°C to 50°C and 17.5°C to 30°C, respectively, within one minute.

The researchers believe their technology also has great potential for other applications, such as sludge dewatering, mining tailings management and resource recovery.

Products from natural gas

Linde Engineering (Pullach, Germany; www.linde-engineering.com) has developed a process to recover helium, hydrocarbons and purified carbon dioxide from natural gas, while conditioning the natural gas for pipeline transport by adjusting the water and heavy-hydrocarbon dew point and the CO_2 concentration. The process — presented at the Gastech conference last month in Houston — combines technologies of BASF SE (Ludwigshafen, Germany; www.basf.com) and Linde.

Helium is commonly recovered from natural gas when a cryogenic separation is employed. The hybrid process eliminates the need for cryogenic conditions, giving access to a new, highly profitable He source. The process consists of two stages of Linde's HiSelect Powered by Evonik membranes, an upstream BASF Durasorb hydrocarbon-removal unit (HRU), an integrated BASF OASE acid-gas-removal unit (AGRU) and an integrated Linde Helium PSA unit. The two HiSelect-membrane stages are simultaneously used for helium enrichment and adjustment of CO_2 to pipeline specification. The PSA purifies the enriched helium up to 99.999% with a high yield. BASF's OASE AGRU is used to selectively remove the CO_2 from an internal recycle without any He or CH_4 loss. BASF's Durasorb HRU removes heavy hydrocarbons and water to meet pipeline dew point, and produce liquid hydrocarbons as valuable byproduct. ■

LINEUP

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Plant Watch

Total-Corbion JV inaugurates PLA bioplastics plant in Thailand

September 13, 2019 — Total Corbion PLA, a 50/50 joint venture (JV) between Total S.A. (Paris, France; www.total.com) and Corbion N.V. (Amsterdam, the Netherlands; www.corbion.com), has inaugurated its polylactic acid (PLA) bioplastics plant in Rayong, Thailand. With a production capacity of 75,000 metric tons per year (m.t./yr), the opening marks the startup of the world's second-largest PLA plant.

Air Liquide to build H_2 manufacturing unit at Shell's refinery in Batangas, Philippines

September 13, 2019 — Air Liquide (Paris, France; www.airliquide.com) signed a contract to supply hydrogen to Shell's Tabangao petroleum refinery in Batangas, Philippines. Air Liquide will invest €30 million to construct a hydrogen manufacturing unit, which will be fitted with a CO_2-recovery process that captures and liquefies CO_2.

Mitsubishi Chemical to increase production of polyester films in Indonesia

September 11, 2019 — Mitsubishi Chemical Corp. (Tokyo; www.m-chemical.co.jp) will invest about $130 million to build a new facility to increase polyester-film production capacity at its Indonesia-based subsidiary, MC PET Film Indonesia (MFI). The new facility, which is slated for completion at the end of 2021, will raise MFI's production capacity to 25,000 m.t./yr.

Air Products announces joint syngas project with Debang Group in China

September 9, 2019 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) announced a new JV with Debang Xinghua Technology Co., a subsidiary of Debang Group, to build, own and operate a coal-to-syngas processing facility in Xuwei National Petrochemical Park, Lianyungang City, Jiangsu Province, China. Air Products will own 80% of the JV and Debang Group will own 20%. The JV will supply syngas to support Debang Group's 350,000-m.t./yr chemical manufacturing facilities. The project is expected to be onstream in 2023.

Messer to build air-separation plant in Indianapolis

September 4, 2019 — Messer Group GmbH (Bad Soden, Germany; www.messergroup.com) is investing €34.6 million ($38 million) in the construction of a new air-separation plant in Indianapolis, Ind. The production plant for oxygen, nitrogen and argon is scheduled to go into operation in early 2021. It will produce gases for the healthcare, chemical, food, glass and metal industries.

Dow to retrofit Louisiana cracker unit to produce on-purpose propylene

August 28, 2019 — The Dow Chemical Co. (Midland, Mich.; www.dow.com) will retrofit proprietary fluidized-catalytic-dehydrogenation technology into one of its mixed-feed crackers in Plaquemine, La. to produce on-purpose propylene. In 2016, Dow expanded the ethylene capacity of this same cracker by more than 225,000 m.t. and added the ability to crack ethane, while maintaining the flexibility to crack propane, butane and naphtha.

Nouryon to double surfactants production capacity in Sweden

August 28, 2019 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) will double capacity at its surfactants plant in Stenungsund, Sweden to support the growth of several existing products, as well as new sustainable technologies for markets, including oil and gas, lubricants and fuels and asphalt. The €12-million expansion and upgrade project includes the installation of a new reactor and is expected to be completed by the first quarter of 2021.

Europe's largest single-train ammonia plant started up with KBR technology

August 28, 2019 — KBR (Houston; www.kbr.com) announced the successful startup of the JSC EuroChem Northwest Phosphorit ammonia plant in Kingisepp, Russia. The facility's 1-million-m.t./yr ammonia production capacity is the largest in Europe. KBR was the technology licensor and provided basic engineering design for the $1-billion project.

Mergers & Acquisitions

DuPont to divest Compound Semiconductor Solutions business

September 10, 2019 — DuPont (Wilmington, Del.; www.dupont.com) signed an agreement to sell its Compound Semiconductor Solutions (CSS) business, which specializes in silicon-carbide (SiC) wafer production, to South Korea-based SK Siltron. The transaction is expected to close by the end of 2019.

New JV to build Thailand's first recycled plastics plant

September 9, 2019 — PTT Global Chemical Co. (Bangkok, Thailand; www.pttgcgroup.com) established a partnership with ALPLA (Hard, Austria; www.alpla.com) to form a JV company called Envicco Ltd. The new JV intends to build Thailand's first plant that will make recycled polyethylene terephthalate (rPET) and recycled high-density polyethylene (rHDPE) plastic resins. This plant will be located at the Asia Industrial Estate in Map Ta Phut, Rayong Province.

DuPont Sustainable Solutions separates from DuPont

September 3, 2019 — DuPont Sustainable Solutions (DSS; www.consultdss.com) announced its launch as an independent global operations management consulting firm, following its separation from DuPont. The decision to create an independent firm responds to a growing client need to rapidly access solutions for evolving global challenges, including maturing systems and processes, the changing workforce, digital evolution and more.

Ube Industries and Kyocera form JV for the manufacture of ceramic filters

September 3, 2019 — Kyocera Corp. (Tokyo, Japan; global.kyocera.com) and Ube Industries, Ltd. (Ube City, Japan; www.ube-ind.co.jp) have signed a JV agreement to manufacture ceramic filters. Under the agreement, Kyocera will acquire 51% of the shares of Ube Electronics, Ltd., a wholly-owned subsidiary of Ube Industries. Kyocera and Ube Industries will then establish a JV named Kyocera-Ube RF TEC Corp., which will begin operations in December 2019.

Evonik purchases surface-modification business unit from Interface Biologics

September 3, 2019 — Interface Biologics Inc. (IBI; Toronto, Ont., Canada; www.interfacebiologics.com) sold its surface modification business to Evonik Industries AG (Essen, Germany; www.evonik.com). The Health Care business line of Evonik will manage the acquired business.

Dow enters partnership with Fuenix focused on recycled feedstocks

August 29, 2019 — Dow signed an agreement with the Fuenix Ecogy Group (www.fuenix.com; Weert, the Netherlands) for the supply of pyrolysis oil feedstock, which is made from recycled plastic waste. The feedstock will be used to produce new polymers at Dow's production facilities at Terneuzen, the Netherlands. This agreement also contributes to Dow's commitment to incorporate at least 100,000 m.t. of recycled plastics in its products sold in the E.U. by 2025.

DIC to acquire BASF's global pigments business

August 29, 2019 — BASF SE (Ludwigshafen, Germany; www.basf.com) and DIC Corp. (Tokyo, Japan; www.dic-global.com) reached an agreement on the acquisition of BASF's global pigments business. The purchase price on a cash and debt-free basis is €1.15 billion. The transaction is expected to close in the fourth quarter of 2020.

TechnipFMC to split into two independent companies

August 28, 2019 — TechnipFMC plc (Houston; www.technipfmc.com) announced its plan to separate into two publicly traded companies: RemainCo, a fully-integrated technology and services provider; and SpinCo, a leading engineering and construction specialist. The separation is expected to be completed in the first half of 2020. ■

Mary Page Bailey

Robots Enter the CPI

Long used for discrete manufacturing, robots are now making their way into product-development laboratories and even producton sites

Unlike some industrial sectors, such as mining and discrete manufacturing, where the use of robotics continues to streamline operations at the expense of jobs normally performed by people, the chemical process industries (CPI) continues to be run, for the most part, by humans operating automated control systems. Nevertheless, the use of robotic technology is slowly being adopted by the CPI to perform routine or monotonous chores, or to carry out tasks that are dangerous. Rather than replacing humans, as has been the case in some sectors, robots in the CPI are instead augmenting the work of chemists and engineers, freeing up their time from mundane tasks in order to use their skills and brain-power for more challenging work.

The use of robotics is increasing in the CPI. Presented here is a selection of recent examples.

Discrete manufacturing

Robots are not new (Note: Already in 1983, this magazine published a Feature Report "Robots in the CPI: An appraisal and a note of caution," *Chem. Eng.* December 29, 1983, pp. 29–34). They have already been used for many years for assembling cars, aircraft, circuit boards and many other manufacturing tasks. Nevertheless, the technology is advancing and the robots are becoming "smarter." In January, for example, Siemens AG (Munich, Germany; www.siemens.com) opened an advanced robotic factory to manufacture battery modules in Tronheim, Norway. The factory comprises a robotized and digitized production line with eight robotic stations and a capacity of 100 MWh/yr. The entire production — from unpacking incoming parts, to testing the finished battery module — is automated. One finished battery is made up of nine modules, each module containing 28 battery cells. The batteries are being produced for the offshore and marine market. The first order was to assemble batteries for use on a drilling rig.

Advisian Digital

FIGURE 1. The patent-pending CAROL can be used for unloading catalysts or adsorbents, while the operator can work safely outside

Robots for safety

This year marked the commercial launch of the world's first robot for catalyst unloading from petroleum-refinery and petrochemical process vessels. Dubbed CAROL (catalyst removal amphirol), the device is a remote-operated, screw-propelled (amphirol) machine equipped with a vacuum hose that can remove solid catalyst material from reactors robotically, allowing plants to avoid subjecting personnel to enclosed work environments and inert atmospheres. Currently, catalyst changeout requires personnel to work inside process vessels with breathing apparatus to remove the materials. CAROL is propelled by dual rotating screws that allow it to move across the surface of solid material (Figure 1, bottom). The robot also has an onboard camera that allows an engineer to operate it safely from outside the vessel (Figure 1, top).

CAROL was developed between 2015 and 2017 by Worley (Brisbane, Australia; www.worley.com), in collaboration with Mecfor (Chicoutimi, Canada; www.mecfor.com), and completed its first in-plant job in 2018 (*Chem. Eng.*, May 2018, p. 9). Today, the CAROL service is commercially available globally, says Chris Jansen, product manager at Advisian Digital (Houston; www.advisian.com) — the independent consulting arm of Worley.

"We have now completed four in-plant jobs to date," says Jansen, "each of which highlights the benefits from the technology." According to Jansen, CAROL has been used for the for the following applications:

- to unload molecular sieves from a dryer at a liquefied-natural-gas (LNG) plant in western Australia — 95% of material was unloaded using the CAROL robot, under dry nitrogen conditions, which eliminated the need for inert entry and saved time by avoiding the need to water-flood the vessel
- to unload catalyst from a gas-shift reactor at a power plant in Mississippi — CAROL operated in vessel temperatures exceeding 120°F, providing time savings by commencing the vacuuming earlier than would otherwise be possible
- to remove ceramics and dense loaded catalyst from a diesel hydrotreater at a refinery in Ed-

monton, Canada — This demonstration showed that CAROL has the potential to limit confined-space entry to removal of the top internal trays

- to remove ceramics from above the top tray and then the carbon from a mercury guard bed at an LNG plant in Queensland, Australia — The use of CAROL in a wet environment, eliminating the need for worker confined-space entry until the final cleaning (accessed via a side manway at the bottom of the vessel)

Mitsubishi Heavy Industries

FIGURE 2. Running tests of the prototype EX ROVR, a plant-inspection robot with explosion-protection features

Although CAROL was specifically designed for catalyst unloading, there is good applicability — with some minor tweaks — outside the downstream oil-and-gas industry, says Jansen. "There are loads of situations involving the requirement for people to enter confined spaces to vacuum granular material," he says.

Meanwhile, in June, Mitsubishi Heavy Industries, Ltd. (MHI; Tokyo, Japan; www.mhi.com) conducted a running test of its prototype EX ROVR (Figure 2), a plant-inspection robot with explosion-protection features to limit the danger of the robot itself igniting an explosion or fire from electric sparks or heat, even in areas with flammable gas. The test was conducted jointly with JXTG Nippon Oil & Energy Corp. at its Mizushima Refinery in Kurashiki, Okayama Prefecture.

During the test, the EX ROVR moved autonomously through several floors of the narrow plant building, including navigating stairs, collected data from its various sensors, and managed continuous automated operation, including charging at a docking station. The robot is still in development, but the test confirmed that it meets the requirements for basic functionality to conduct routine patrol inspections at JXTG Energy's plant, and handle emergency situations, says MHI.

MHI is developing the explosion-proof plant inspection robot based on its success with robotics technologies in such areas as support for nuclear plant accident containment. The EX ROVR has an explosion-proof design that complies with Japan's explosion-proof guidelines, as well as the ATEX and IECEx explosion-protection standards widely adopted in Europe and around the world, allowing it to be used safety in areas with an explosive gas atmosphere (Zone 1). MHI will conduct further tests and demonstrations in a range of plant environments in order to improve the check density and enhance safety, with the aim of commercialization.

MHI has also developed two firefighting robots: the Water Cannon Robot and the Hose Extension Robot. As a team, they are expected to play an active role in situations too hazardous for firefighting crews, such as fires at petrochemical plants. The Water Cannon Robot can extinguish and cool fires where human intervention

Clariant

FIGURE 3. Robots are featured in this new high-throughput experimentation (HTE) laboratory that opened last month in Houston

Evonik Industries

FIGURE 4. This fully automated plant enables testing coating formulations much quicker than having the tests performed manually

is difficult, while the Hose Extension Robot automatically lays out up to 300 m of fire hose to supply water to the Water Cannon Robot. Together, the two robots, when integrated with a "reconnaissance and surveillance robot" (available in aerial and ground models) and a command system, constitute a Firefighting Robot System. The system is designed for installation on a dedicated transport vehicle that can be brought directly to the location of the fire.

Meanwhile, in May, Invert Robotics Ltd. (Christchurch, New Zealand; www.invertrobotics.com) closed a $8.8-million round of financing led by Finistere Ventures, an agtech/foodtech venture pioneer, with support from Yamaha Motor Ventures & Laboratory Silicon Valley, the corporate venture capital business of Yamaha Motor Co. Existing investors, including Allan Moss, Inception Asset Management and the New Zealand Venture Investment Fund also participated.

The young company (founded in 2010) plans to use the investment to scale its team, open a U.S. office and expand its technology platform. Invert Robotics developed what is said to be the first climbing robot specifically designed to inspect the integrity and safety of non-magnetic, hazardous environments.

The "crawler" is based around a patented sliding suction principle. The suction provides a 4x redundancy in adhesion, enabling the crawler to move over surface discontinuities, such as lapped joints or edges of panels. Two models are available with either active or passive suction. The default payload is a high-resolution camera that feeds high-definition video to operators in real time. It can also carry a payload of up to 5 kg for performing other non-destructive testing (NDT). "We are increasing the NDT options on the robot," says James Smith, global petro-chemical sales manager at Invert Robotics B.V. (Eindhoven, the Netherlands). "In addition to current capabilities in visual and ultrasound testing, we are also exploring using pulsed eddy current probes," he says.

According to the company, a robotic inspection takes an average of two hours per tank, and eight hours per dryer. In contrast, traditional man entry in a vessel can take up to three days, due to the need for erecting scaffolding or platforms.

The technology was first commercialized in 2010, with a focus on the food-and-beverage industry. Since then, the robot has been leased to "a handful of organizations," and conducted thousands of inspections in this sector, says Smith. "We only entered the chemical industry in 2017, and since then, we have worked with many of the largest players in oil, gas and chemicals industries," he says.

Faster product development

Although there are many automated tools available for laboratory work, it is fairly recent that the use of robotics has moved further up the product-development chain. Just last month, for example, Clariant (Muttenz, Switzerland; www.clariant.com) opened its new high-throughput experimentation (HTE) laboratory in Houston (Figure 3). Said to be a first-of-its kind supporting the oil-and-gas industry, the HTE laboratory is a fast-response-unit for application, discovery and development of optimized formulations used in the oil-and-gas industry.

In 2017, Evonik Industries AG (Essen, Germany; www.evonik.com) opened a new fully automated plant for testing coating formulations. This plant consists of 52 elements that are combined in 30 functionalities. Each functionality is designed to handle a specific task, such as applying a coating formulation to a substrate. The 52 elements are connected by a rail system, on which containers and substrates are transported by shuttle. There are 13 robots that perform various tasks, such as loading the shuttle, or placing coated substrates in the oven. An average of 120 samples can be formulated in the plant in 24 hours.

A glimpse of the future potential of robotics in product development can be found in the August 9 issue of *Science*, where researchers from the Massachusetts Institute of Technology (MIT; Cambridge, Mass; www.mit.edu) reported on the development of an automated platform for performing the synthesis of organic compounds, using artificial intelligence (AI) for planning, and robotics for performing the synthesis in flow reactors. The technology "has the promise to help people cut out the tedious parts of molecule building," including looking up potential reaction pathways and building the components of a molecular assembly line each time a new molecule

Patrick Kern, KIT

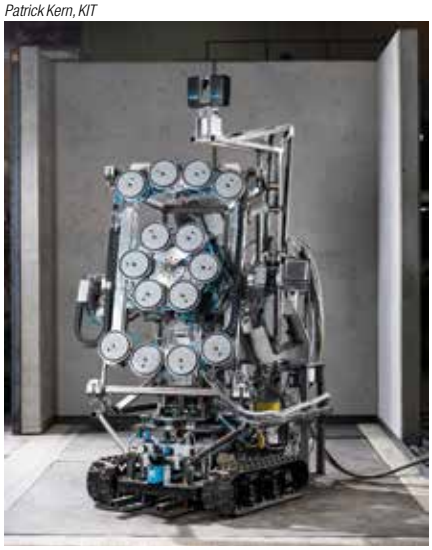


FIGURE 5. The manipulator measures radioactive contamination of surfaces, decontaminates them, and measures them again

is produced, says Klavs F. Jensen, the Warren K. Lewis Professor of Chemical Engineering at MIT, and co-leader of the project.

The system performs three steps. First, AI-guided software suggests a synthesis route. This open-source software performs computer-aided synthesis planning (CASP) trained on millions of reactions from Elsevier's Reaxys database and the U.S. Patent and Trademark office. Chemists then review and refine the synthesis into a recipe, which is then sent to the robotic platform that automatically assembles the required hardware (reactors and separators) into a continuous flow path, and performs the reactions. The robot also connects reagent lines and computer-controlled pumps to reactor inlets through a fluidic switchboard.

According to the authors, the strategy "augments a chemist's ability to approach target-oriented flow synthesis while substantially reducing the necessary information gathering and manual effort."

To demonstrate the system, 15 drug or drug-like molecules were predicted and then synthesized, with processes taking from between two hours for the simplest molecules, to about 68 hours for making multiple compounds. The research received support, in part, from the U.S. Defense Advanced Research Projects Agency (DARPA) Make-it program.

Robots for decontamination

In June, Robdekon — the Central Hub for the Development of Robots for Decontamination Tasks — officially opened in Karlsruhe, Germany. Robdekon is one of two competence centers for robotic systems, which the Federal Ministry of Education and Research (BMBF; Bonn, Germany; www.bmbf.de) has funded since 2018 as part of the Research for Civil Security program. The center is coordinated by the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB; Karlsruhe, Germany; www.iosb.fraunhofer.de), with partners from industry and research institutions. The aim of the competence center is to act as an expert and user network for new decontamination technologies using robots.

For example, six professors from the Karlsruhe Institute of Technology (KIT; www.kit.edu) are involved in projects focused on robot systems to autonomously carry out decontamination work at, for example, nuclear power plants. Scientists of the Chair of High-Performance Humanoid Technologies (H^2T) and the Intelligent Process Automation and Robotics Lab (IRP) design and build robot systems to clean or disassemble radioactively (Figure 5), biologically or chemically contaminated surfaces or system components.

Within the competence center, Fraunhofer IOSB will concentrate on further developing the autonomy of construction machinery. "Within Robdekon, we will contribute our toolbox of algorithms for autonomous mobile robot systems," says Christian Frey, the responsible department head. "These algorithms are used to navigate in rough terrain, avoid obstacles and control manipulators, for instance, for an excavator shovel to take up contaminated material and unload it at a desired location," he says.

Industrial partners within Robdekon are Götting KG, Kraftanlagen Heidelberg GmbH, ICP Ingenieursgesellschaft Prof. Czurda and Partner mbH, and KHG Kerntechnische Hilfsdienst GmbH. ■

Gerald Ondrey

Building a Better Liquid-Dosing System

Modernized pumps and advanced controls improve accuracy and repeatability of liquid dosing systems

Whether the application is dosing chemicals for process or water treatment, whether it's batch or inline dosing and whether it's continuous or intermittent flow, at its heart, successful liquid dosing is really based upon choosing the proper pump and controls. But, therein lies the real challenge — how do you select the right equipment and assemble it into a system that is compatible with the chemistry, while providing the accuracy and repeatability necessary for the process? Fortunately, several advances in pump and control technologies are making it possible to design the liquid-dosing system that best meets the needs of your process.

Chemical-compatible pumps

There are many challenges associated with the chemicals being dosed, such as corrosiveness, potential for off gassing, high temperatures and viscosity, and any issues must be addressed when designing a liquid dosing system in order to provide accuracy, repeatability and reliability.

"First and foremost, the processor needs to consider chemical compatibility," says Brian Ellingwood, technical sales coordinator with IVEK (North Springfield, Vt.; www.ivek.com). "Often there are chemicals that are corrosive or other hazardous materials that may be used in process."

One of the ways manufacturers of dosing system components are handling chemical compatibility is by using advanced materials. For example, IVEK offers positive displacement pumps and valves in its product line. "We use ceramic because it is chemically inert. It enables us to take on a wide scope of projects while maintaining the integrity of the fluid handling process," says Ellingwood. Recently, the company expanded its ceramic capabilities.

"We make and custom machine our own ceramics. While our primary ceramic has always been aluminum oxide, which is very hard, durable and non porous, there are chemistries where it is not compatible. We've expanded our capabilities and now offer zirconia with different stabilizers for a variety of applications. We also offer silicon carbide, which is ideal for hydrofluoric acid, a damaging, dangerous and difficult material to work with."

Another consideration is off-gassing, says Mark Girgenti, lead design engineer with Burt Process Systems (Hamden,

Burt Process Systems

FIGURE 1. Burt Process's ChemPlus chemical feed systems are pre-engineered chemical injection systems that provide flexibility in metering pump options and controls to meet the chemical and corrosion resistance requirements, as well as control needs for each application

ProMinent

FIGURE 2. ProMinent offers metering pumps with predictive intelligence such as the Gamma L and Gamma XL, which can be combined with the DULCOnneX platform to allow efficient and fault-free system operation, which the operator can access from anywhere

CONSIDERATIONS WHEN SELECTING A LIQUID-DOSING SYSTEM

While pumps and controls are becoming more modern, employing the latest technology won't provide the necessary accuracy and repeatability if it is not the correct equipment for your application. EPIC Process System's Ken Sipes provides some helpful information on making sure the system you end up with is properly designed and engineered for your process.

The first thing a system designer needs to know is the chemistry, or formula card, for the application. "This usually entails a number of different raw materials that are purchased in bulk from other chemical manufacturers and blended together to make the end product," says Sipes. "Once we know what all the different ingredients are, we need to know how much of each goes into the process and, typically, there is an aspect of what level of accuracy is needed in dosing. The third component is the order of addition of the raw materials."

When considering inline blending, knowing the necessary level of accuracy and order of addition is as important as understanding the characteristics of the raw materials. "Some chemistries are reactive as opposed to being a simple mixture. In those cases, accuracy is important because you are trying to force a reaction, control the reaction or to keep the reaction at a certain spot," he says. "Order of addition is important because Chemical A and Chemical B may react poorly together, but if you first mix Chemical A and Chemical C, then add Chemical B, the reaction may be what you're looking for."

From there, it is important to consider the difference between batch and inline dosing. "Batch can be more economic from the initial investment standpoint, as it often requires less equipment and instrumentation and offers flexibility for formula changes that may occur down the road," Sipes explains. "However, inline dosing and blending offers some advantages over batch related to space requirements and production productivity because there's less equipment volume to clean during product changeovers."

For example, manufacturers of detergent often make a "base" or "neutral" batch over and over again in large blend tanks and then pump it to fillers; however, before it goes to filling, the processor may dose the colors and fragrance near the filler, inline, so the amount of equipment and piping that has to be cleaned is minimized versus making the same finished product in large blend tanks. "A lot of processors are considering moving to inline operations for this reason, but they aren't sure their formula can be done inline."

To help, EPIC offers a small, demonstration inline blending skid (Figure 5). "If the chemicals aren't hazardous or proprietary, we can run a trial in our facility or, if they are hazardous or proprietary, we can ship the skid to their site and they can run the test." If the inline process passes QC tests and the processor elects to go to an inline system, we can then build one to their capacity. "Many customers are unsure about inline blending because they don't want to risk investing in equipment and find that it won't work in their application. The demo-scale skid we offer gives them the confidence to move to a production-scale system if that is appropriate. ❑

Conn.; www.burtprocess.com). "Certain chemicals will release themselves into a gas, so when they are injected, particularly at low flow rates, the recessed cavities of certain pumping technologies can allow the gas to build up, causing system failure or causing the system to inject the wrong amount of chemistry."

New pumping technologies allow for degassing of systems. "One of the newer metering pumps we use has built-in degassing, where it bumps the motor into stand-by mode in order to allow it to remove the gas from the system prior to injection."

Similarly, if a metered fluid is very hot, toxic or highly viscous, this can be a problem, says Michael Birmelin, marketing editor, with ProMinent GmbH (Heidelberg, Germany; www.prominent.com). "In difficult dosing applications, it's important to use hermetically sealed metering units with wear-free diaphragms, which offer the ability to optimize dosing precision, even under tough conditions."

The physical properties of the chemical being dosed can also create challenges, notes Ken Sipes, director of engineering for process systems with EPIC Process Systems (St. Louis, Mo.; www.epicmodularprocess.com). "Many metering applications require low or very low flowrates. If you are pumping a slurry with suspended solids or abrasive materials, there's a chance the fluid may erode or damage the equipment or valves. Without proper equipment and material selection, the system will have great difficulty in metering accurately and consistently. There are many ways this can be accom-

IVEK

FIGURE 3. IVEK's Digispense 4000 programmable liquid dispensing system enables precise and repeatable fluid dispensing volumes at rates of 2 nL/s to 300 mL/s

modated. It's a best practice to understand the process, consider the challenges and find the right pumping and control solution."

Smarter, for better accuracy

Accuracy is important in liquid dosing for two reasons, says IVEK's Ellingwood. "First, achieving repeatable and consistent product each and every time is essential in the process industry. Second, the chemicals being dosed could be very expensive material that must be tightly controlled and not wasted," he says.

"While it's key to repeatable and consistent product, getting accurate flow data is one of the greater challenges when designing a liquid dosing system," explains Burt Process's Girgenti. One thing that is helping is the development of smarter pumps paired with advanced control systems, he says. "In these cases, we've been employing smart pump technologies that can measure the volume of the chamber and provide a realtime flow measurement, allowing users to move away from adjusting stroke length toward a computer-controlled system that allows them to monitor and measure the volume of what is being dosed." Other options include higher-end controls that communicate with the plant to provide realtime data and control the pumps locally, he says. "We are starting to see modernization and a move toward smart dosing pumps and higher-end control systems in the chemical feed and liquid dosing industry."

AW-Lake

FIGURE 4. AW-Lake provides smart batch controllers, such as the MX 9000, that can "learn" the process in order to get the most accurate volume possible

Combining the two, Burt Process's ChemPlus chemical feed systems (Figure 1) are pre-engineered chemical injection systems that provide flexibility in metering pump options and controls to meet the chemical- and corrosion-resistance requirements, as well as control needs for each application.

ProMinent's Birmelin agrees that advanced pumps and controls are the latest development: "The amount of data generated by sensors and pumps will increase significantly in the future. A wide range of information needs to be recorded, provided and efficiently used in process control. Therefore, processors need data-based operating models, which require a high degree of mobility and transparency. So we are moving towards digital solutions that allow users to gather the relevant data and make them available where it is needed. These internal data are linked with external data and used to optimize operating processes."

As such, ProMinent offers metering pumps with predictive intelligence, such as the Gamma L and Gamma XL, which can be combined with the DULCOnneX platform to allow efficient and fault-free system operation, which the operator can access from anywhere (Figure 2). Devices can be fully integrated and accessed both locally and remotely. Processors benefit from direct access to the information about installed devices and systems. Calibration data, parameter sets or error messages create a comprehensive overview of process

EPIC

FIGURE 5. Many processors are unsure about inline blending because they don't want to risk investing in equipment and find that it won't work in their application. The demo-scale skid offered by EPIC gives them the confidence to move to a production-scale system if that is appropriate

conditions, such as operating time, dosed volumes and pressure conditions, which can be called up to the current status or retrospectively.

Other components are also gaining intelligence as liquid dosing moves toward modernization, say the experts. For example, IVEK offers its Digispense 4000 programmable liquid dispensing system (Figure 3). The unit enables precise and repeatable fluid dispensing volumes at rates of 2 nL/s to 300 mL/s, as well as various production dispensing and metering modes that optimize the fluidic requirements. The control package also offers improved integration to programmable logic controller (PLC) systems. This is facilitated by Ethernet fieldbus communication options and web browser services. This communication allows processors to remotely monitor and control pumps through their computer network.

Likewise, AW-Lake Company (Oak Creek, Wis.; www.aw-lake.com) offers smart batch controllers, such as the MX 9000, that can "learn" the process in order to get the most accurate volume possible (Figure 4). "The controllers gage how long it takes for the valves to open and close and adjust accordingly," says Mark Iverson, general manager with AW-Lake. "For example, if the processor is doing a 50-gallon batch, our batch counter will count up to 49 gallons and will close the high-flow valve and switch to the low-flow valve from 49 to 50 gallons and then close the low-flow valve. If the controller sees that the dose was over by 0.1 gallons, it will recognize this and adjust until it reaches the precise volume. This intelligence helps achieve accuracy and repeatability in the process."

EPIC's Sipes says these smarter, more automated pieces of equipment are coming together to improve the accuracy, repeatability and reliability of liquid dosing. "Better control can help minimize waste and create repeatability and consistency by taking error out of the equation," he says. "The industrial internet of things (IIoT) and real-time data and diagnostics are starting to be deployed in liquid dosing applications, where, with the right sensors, instrumentation and equipment, the control system can watch a system perform and run. It can use artificial intelligence to learn what are normal operating conditions and what are not. Processors can collect those data and realize when preventive maintenance is needed base on operational history. Not only does this optimize the liquid-dosing application, but overall it improves uptime and profitability of the plant." ■

Joy Le Pree

For more technical information on metering pumps, see "A Primer on Reciprocating Metering Pump Technologies," *Chem. Eng.*, September 2019, pp. 47–53; or in the *CE* archives at online at www.chemengonline.com.

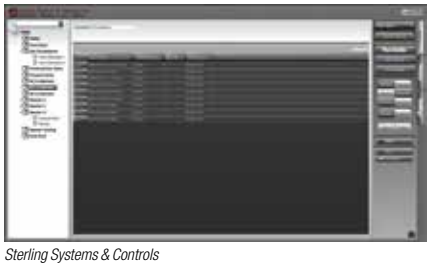
Focus on Maintenance Tools

Sulzer Pumps Finland

Wireless condition monitoring for rotating machinery

Last month, this company introduced the Sulzer Sense wireless IoT condition-monitoring system (photo). The solution includes wireless sensors that are attached to a pump, agitator, motor or any rotating equipment. The sensors measure temperature and vibration and send the data to the cloud. This means that the operating status of the equipment can be remotely monitored 24 hours a day, seven days a week. The condition-monitoring feature identifies changes in condition parameters and indicates potential faults at an early stage. The new Sulzer Sense monitoring device will detect possible imbalance, misalignment, looseness and bearing wear. This supports predictive maintenance and helps to avoid sudden pump failure and eventual downtime. The Sense data are sent to the cloud and can be monitored in the company's online service on a mobile phone, tablet or laptop, anywhere and anytime. The user can set an alert value and will automatically be alarmed if this value is exceeded. — *Sulzer Pumps Finland Oy, Vantaa, Finland*
www.sulzer.com

SKF USA



Sterling Systems & Controls

Handheld device makes machine monitoring easy

SKF Pulse (photo) combines an easy-to-use handheld sensor with a new mobile application (app), allowing users to quickly monitor rotating equipment and machine health to predict issues and improve reliability before operations are impacted. For more advanced analysis, users can request a Pulse Check directly via the app. The request goes to a diagnostics center operated by this company, where experts remotely analyze the machine data and respond with recommended corrective actions to improve equipment performance, if required. SKF Pulse has an intuitive visual interface that guides users through the data collection process. Users enter asset information that automatically configures alarm thresholds based on ISO standards. Thresholds can also be customized if desired. The durable SKF Pulse sensor features: velocity, acceleration and temperature measurement of rotating equipment; Bluetooth communication with iOS mobile devices; and more. — *SKF USA Inc., Lansdale, Pa.*
www.skf.com

Emerson Automation Solutions

Software for managing preventive maintenance

PMPlanR is a robust standalone preventive-maintenance planning software application. PMPlanR allows users to "build your plant." Each plant (or multiple plants) consists of areas, machines and assets. In addition to the Plant Builder function (photo), users can set up and manage part vendors, service tags, preventive-maintenance tags and work orders, as well as prepare and display various history reports that users have access to. A security system is also provided in the PMPlanR software application. WebPM remote supervisory software option is available for use with the PMPlanR application. WebPM gives corporate users access to the database of the PMPlanR software application, which allows remote users to view and print historical reports. — *Sterling Systems & Controls, Inc., Sterling, Ill.*
www.sterlingcontrols.com

Prescriptive analytics for improved reliability

Released in May, PeakVue Plus (photo) is a technology enhancement that brings prescriptive analytics to the field to help users improve the availability of rotating machinery. The firmware streamlines the path from data collection to action and enables users to make timely, corrective decisions when analyzing machinery vibration. By embedding expertise into analysis algorithms, PeakVue Plus enables AMS 2140 Machinery Health Analyzer users to see at a glance not only whether a machine is in good working condition, but also the severity of an issue and whether it is related to a bearing defect or lubrication. This helps field technicians determine root causes and quickly resolve equipment problems before failures occur and cause

Note: For more information, circle the 3-digit number on p. 82, or use the website designation.

unplanned downtime. PeakVue Plus builds on proven PeakVue technology that filters vibration signals to focus on impacting, a leading indicator of overall asset health on any type of rolling-element bearing machine. — *Emerson Automation Solutions, Austin, Tex.*
www.emerson.com

This handheld device analyzes motor circuits

All-Test Pro

This company provides industry with advanced handheld predictive-maintenance testing and troubleshooting instruments for a.c. and d.c. motors, transformers and generators. A recent addition to the product slate is a new series of Motor Circuit Analysis (MCA) instruments (photo) that deliver a total view into the condition of an electric motor, transformer or generator. They represent the 7th generation in product innovations that ensure the reliability of motors in the field and help to maximize the productivity of maintenance teams everywhere. — *All-Test Pro, LLC, Old Saybrook, Conn.*
www.alltestpro.com

New software release to optimize plant performance

In July, this organization launched the latest release of its AllAssets, adding significant new functionality to the AllAssets Asset Performance Management (APM) platform with the addition of a Maintenance Optimization module. The software includes RCM, FMEA, FMECA and maintenance-optimization capabilities and libraries. The company's approach to APM brings together facility-specific asset data and engineering expertise with industry best practice. The platform's sophisticated, risk-based algorithms and library of extensive engineering knowledge across reliability and maintenance optimization enable users to determine the most effective maintenance strategies. With the tool, maintenance costs can be reduced by up to 30%, says the company. — *Lloyd's Register, London, U.K.*
www.lr.org

A tablet PC for hazardous and non-hazardous locations

The Field Xpert SMT70 (photo) is a rugged tablet PC for commissioning and maintenance staff to manage field instruments and document the work progress. The tablet comes preinstalled with DeviceCare device configuration software and device library. The Field Xpert SMT70 supports HART, Profibus DP/PA, Foundation Fieldbus, Modbus, CDI and this company's service interfaces. It can connect to field instrumentation devices directly via a USB or Bluetooth wireless modem, or via a gateway, remote I/O or multiplexer to a bus system. The Field Xpert device library has more than 2,700 preinstalled device and communication drivers, allowing it to work with many different instruments from a wide variety of vendors. The drivers can be used to communicate with virtually all HART and Foundation Fieldbus devices, and additional device drivers (DTMs) can be easily installed if required. The tablet comes in a general purpose configuration, as well hazardous-area configuration for Class 1, Division 2 Groups A,B,C,D, T4 and Class 1, Zone 2, Groups IIC, T4. — *Endress+Hauser, Greenwood, Ind.*
www.us.endress.com


Endress+Hauser

Load monitoring relay for direct-current applications

The SIRIUS 3UG546 DC load monitoring relay is said to be the most compact of its kind for d.c. applications, enabling simple and precise power measurement. It is the first and only d.c.-load-monitoring relay to combine current and voltage measurement, power monitoring, communication and various other useful functions in one single, compact device. Until now, several individual components were required for each of these functions. The load-monitoring relay features a large operating voltage range from 0 to 800 V. The relay comes with separate counters for energy consumption and energy recovery. Operating-hour and switching-cycle counters enable preventive maintenance. — *Siemens AG, Munich, Germany*
www.siemens.com

Gerald Ondrey

New Products

Mann+Hummel International

This compact air filter is highly energy efficient

The Aircube Eco 4V ePM1 60% compact air filter (photo) is designed for the filtration of indoor air in buildings and process units. The filter conforms to the ISO 16890 standard and has an A+ energy rating according to Eurovent. The filter is said to have the lowest energy consumption on the market and fulfills all the relevant standards with regard to hygiene (VDI 6022), including the EN13501 E d0 fire-protection standard. In addition, the FDA requirements to enable use in the pharmaceutical and food industries (EG 1935/2004 and EU10/2011) are fulfilled. The materials used are free of animal-derived ingredients (ADI free) and meet the requirements of the ISO 846 standard with regard to the growth of microorganisms. — *Mann+Hummel International GmbH & Co. KG, Ludwigsburg, Germany*
www.mann-hummel.com

Larson Electronics

A new explosion-proof motor for hazardous locations

The new EXP-MTR-1P-115.230-2HP-3.6K-56HC fractional explosion-proof motor (photo) is rated for use in Class I, Divisions 1 and 2, Groups C and D; and Class II, Divisions 1 and 2, Groups E, F, and G hazardous locations. This thermally protected unit has a 2-hp motor that offers 9.8 full-load A and 4.4 A of non-load current. The motor can generate 3,450 rpm and provides 3 ft-lb of torque with 120% locked-rotor torque and 250% breakdown torque. The motor is fully enclosed (IP55 rated), fan-cooled and has an ambient temperature rating of 50ºC. — *Larson Electronics LLC, Kemp, Tex.*
www.larsonelectronics.com

Alfa Laval Kolding

This valve sensing-and-control unit has been re-engineered

The second-generation ThinkTop V50 and V70 control units have been re-engineered to offer fast and intuitive setup and commissioning; a repositioned Gore vent; a more compact and aesthetic design; burst-seat clean functionality; and a QR code for easy online access to supplementary materials and direct support. The new automated setup feature offers manufacturers quick, easy commissioning — up to 90% faster than the previous generation, says the manufacturer. The new ThinkTop fits on any of this company's valves, making it suitable for all retrofits. It features self-diagnostics, checking and remedying operations when required, and an enhanced 360-deg LED visual-status indication so that operators can clearly see the valve status from any location on the production floor. Furthermore, the new ThinkTop V50 and V70 meet the protection classes IP66, IP67 and IP69K. — *Alfa Laval Kolding A/S, Kolding, Denmark*
www.alfalaval.com

Brüel & Kjær Vibro

This machinery protection system has SIL-2 certification

The VC-8000 Setpoint machinery-protection system (photo) has received SIL-2 certification, allowing it to be specified and used as part of SIL-rated functional safety applications. These typically include, but are not limited to, radial vibration, axial position and bearing temperature measurements commonly encountered in machinery-protection systems on pumps, motors, compressors, turbines and other critical rotating and reciprocating machinery. The system underwent rigorous independent testing and evaluation as part of this third-party certification process to ensure compliance with ISO 61508 and ISO 61511 standards. These sectors typically require full compliance with American Petroleum Institute (API) Standard 670 for Machinery Protection Systems, cybersecurity certification to standards such as IEC 62443, and SIL certification to ISO 61508 and 61511. The VC-8000 is now compliant with the rigorous requirements of all three. — *Brüel & Kjær Vibro GmbH, Darmstadt, Germany*
www.bkvibro.com

Automated viscometer performs high-throughput analysis

The automatic VROC initium Model II viscometer (photo, p. 27) is now available for viscosity characterization of any solvent-based solutions. VROC (viscometer-rheometer-on-a-chip)

technology combines microfluidic and MEMS (micro-electro-mechanical systems) technologies to measure dynamic viscosity over a wide range of operation. High-throughput and timely measurements are now easier to perform and more productive, says the company. Accurate and precise viscosity measurement is assured with self-diagnosis, leaving no uncertainty. The viscometer can measure intrinsic viscosity and true viscosity, even at high shear rates up to 148,000/s with minimal sample volume. Sample recovery after measurement helps save samples for further analysis. The system performs viscosity analysis of the sample for the process and quality control, or for product development. Samples placed in a vial rack or 96-well plate are automatically picked up and tested. Larger payloads of solvent bottles allow measurement of 96 samples with a single charge of solvents. — *RheoSense, Inc., San Ramon, Calif.*

www.rheosense.com

This mixer features built-in powder-induction technology

VersaMix multi-shaft mixers (photo) incorporate a proprietary powder-induction feature for efficient charging of thickeners to produce high-quality gels, creams and pastes. The VersaMix includes a three-winged anchor and a high-speed disperser blade, which provide a robust combination of shear and bulk flow at various stages of the mixing cycle. The third agitator, a rotor-stator emulsifying head, showcases the unique Solids/Liquid Injection Manifold (SLIM) technology for convenient subsurface raw-material additions. All shaft seals are lubricant-free. Operated from an 11-in. touchscreen, a recipe system enables convenient batching based on speed, time, temperature and vacuum level. The VersaMix is available in laboratory-scale and production sizes upwards of 2,000 gal. — *Charles Ross & Son Co., Hauppauge, N.Y.*

www.mixers.com

Mary Page Bailey and Gerald Ondrey

RheoSense

Charles Ross & Son

Safety Instrumented Systems and Risk

Department Editor: Scott Jenkins

Within the chemical process industries (CPI), the need to design safety systems to prevent process failures from occurring, or to control them when they do, is well recognized, as is the importance of having confidence in the safety systems that are put in place. However, when formalized, the specific terminology, definitions and concepts are sometimes misunderstood, misinterpreted or implemented incorrectly. Provided here is a review of terms and definitions related to determining safety integrity levels (SILs).

Functional safety standards

Functional safety refers to the ability of safety-relevant electronic devices to respond reliably and verifiably to signals that they receive. Industry experts have addressed functional safety and formalized an approach for reducing risk in process plants through the development of industry consensus standards. Those most relevant for the CPI include IEC 61508, IEC 61511, and ANSI/ISA 84, developed by the International Electrotechnical Commission (IEC; Geneva, Switzerland; www.iec.ch) and the International Society of Automation (Research Triangle Park, N.C.; www.isa.org). IEC says the aim of functional safety is to reduce safety risks to tolerable levels and reduce the negative impacts of safety failures. The standards mentioned here emphasize quantitative risk reduction, lifecycle considerations and general practices, while acknowledging that a system with zero risk is not possible. Functional safety is measured by assessing how likely it is that a particular adverse safety-risk event will occur and how severe it would be (how much harm it could cause).

SIF, SIS and SIL

A safety instrumented function (SIF) refers to the means by which the risk of a particular safety hazard is reduced automatically by the sensors, logic solvers and final elements (for example, safety relief valve) that are used. A safety instrumented system (SIS) is the safety system used to implement a SIF. The safety integrity level (SIL) is a measure of safety system performance, in terms of the probability of failure on demand (PFD). SIL is intended as a shorthand indicator for quantifying the risk-reduction capacity of a safety system. The SIL category of a system is generated by combining the likelihood of a safety failure with the consequences of a failure. There are four discrete integrity levels associated with SIL: SIL 1, SIL 2, SIL 3 and SIL 4. The higher the SIL level, the higher the associated safety level, and the lower probability that a system will fail to perform properly. As the SIL increases, typically the installation and maintenance costs increase, as does the complexity of the system.

TABLE 1. SIL CATEGORIES FOR INTERMITTENT OPERATION

SIL class	Probability of failure on demand (PFD)	Risk reduction factor (RRF)
SIL 1	0.1– 0.01	1 to 100
SIL 2	0.01–0.001	100 to 1,000
SIL 3	0.001–0.0001	1,000 to 10,000
SIL 4	0.0001–0.00001	10,000 to 100,000

TABLE 2. SIL CATEGORIES FOR CONTINUOUS OPERATION

SIL class	Probability of dangerous failure per hour of operation (PFH)	Risk reduction factor (RRF)
SIL 1	10^{-5} to 10^{-6}	100,000 to 1,000,000
SIL 2	10^{-6} to 10^{-7}	1,000,000 to 10,000,000
SIL 3	10^{-7} to 10^{-8}	10,000,000 to 100,000,000
SIL 4	10^{-8} to 10^{-9}	100,000,000 to 1,000,000,000

To determine SIL categories, a risk matrix is constructed that matches likelihood of occurrence against the consequences of the event. The likelihood ranges from frequent to incredible, and the consequences range from negligible consequences to catastrophic. The four SIL categories are shown in Tables 1 and 2. For systems that operate intermittently, PFD is used, while probability of failure per hour (PFH) is used for continuously operating systems.

End-user responsibility

A SIL rating applies to SIFs and SISs, and is not assigned to individual products or components. Rather, products and components are said to be suitable for use within a given SIL environment. The end user of the sensors, logic solvers and final elements are responsible for implementing the safety system correctly, so that it achieves the risk reduction that is sought. Having components that are suitable for SIL 3, for example, does not, on its own, ensure that the system will achieve SIL 3.

Risk tolerance is subjective and site-specific. Each owner/operator needs to determine the acceptable level of risk to personnel and capital assets based on company philosophy, insurance requirements, budgets, and a variety of other factors. A risk level that one owner determines is tolerable may be unacceptable to another owner.

When determining which SIL is needed for a given system, the first step is often conducting a process hazard analysis (PHA). This will assist in determining the functional safety need and in identifying the tolerable risk level. The degree of risk reduction and mitigation due to the basic process control system (BPCS) and other layers of protection are taken into account. Then, plant operators compare the residual risk against their risk tolerance. If the risk level remains unacceptably high, a risk-reduction factor (RRF) is determined and a SIS/SIL requirement is calculated (RRF is the inverse of the PFD for the SIF/SIS). ■

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Production of 2-propylheptanol

By Intratec Solutions

Also known as 2-PH and 2-propylheptyl alcohol, 2-propylheptanol is a branched fatty alcohol, primarily used in the production of plasticizers and surfactants applied in detergents or industrial cleaning agents, as well as in the manufacture of lubricants and acrylates in adhesives applications.

This fatty alcohol is produced at commercial scale mainly by the hydroformylation of *n*-butenes to aldehyde (oxo synthesis), followed by aldol condensation and hydrogenation steps. In the process under analysis, 2-propylheptanol is produced from butenes and synthesis gas (syngas). The process examined is similar to the LP Oxo technology jointly licensed by Johnson Matthey Davy (London, U.K.; www.matthey.com) and Dow Chemical (Midland, Mich.; www.dow.com).

The process

The process comprises three major sections: hydroformylation; aldolization; and hydrogenation (Figure 1).

Hydroformylation. Syngas and raffinate-2 (C4 residual containing butenes and butane) are purified in order to protect the biophosphite-modified rhodium catalyst. A stirred-tank reactor receives the raw material feed and a catalyst solution. The butylenes react with carbon monoxide and hydrogen at mild temperatures and low pressures, yielding valeraldehyde. The crude reaction product is fed to a degasser, where dissolved lights vaporize. The vapor stream is mixed with reactor vent gases and is recycled to the reactor after pressurization. The liquid is heated in a vaporizer and then fed to a flash vessel, where a concentrated catalyst solution is separated from a vapor phase containing hydroformylation products and remaining reactants.

Aldolization. The vapor stream from the flash vessel is freed from residual butenes and butanes (which are sold as fuel). The resulting valeraldehyde-rich liquid is fed to a stirred tank along with a caustic soda solution catalyst. An aldolization reaction occurs, yielding 2-propyl-2-heptenal and water. The effluent is sent to a reactive column, which strips off light ends and unreacted valeraldehyde from the reactor effluent. In a decanter, the liquid stream is separated into caustic soda solution and 2-propyl-2-heptenal.

Hydrogenation. The 2-propyl-2-heptenal solution is distilled from heavy ends, which are separated from the 2-propyl-2-heptenal stream in the column bottom. The overhead outlet is condensed and is submitted to a liquid-phase hydrogenation in two steps, carried out over heterogeneous catalysts, yielding 2-propylheptanol. The products are then submitted to a fractional distillation step, in which pure 2-propylheptanol is separated from light-ends and other impurities.

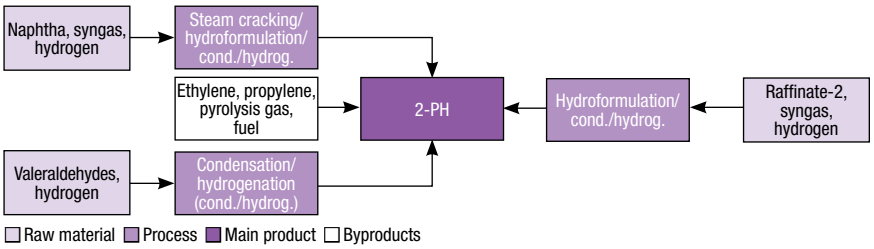

FIGURE 2. Several production pathways exist for 2-propylheptanol

Production pathways

Commercial production of 2-propylheptanol is based on valeraldehyde raw material, in such a way that different manufacturing routes are related to different sources of such raw material. Valeraldehyde, in turn, is obtained primarily from butylenes via oxo processes. Different pathways for 2-propylheptanol production are presented in Figure 2.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce 2-propylheptanol was about $850 per ton of 2-propylheptanol in the fourth quarter of 2015. The analysis was based on a plant constructed in the U.S. with the capacity to produce 120,000 metric ton per year of 2-propylheptanol.

This column is based on "2-Propylheptanol Production Process - Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/2-propylheptanol-production-cost. ■

Edited by Scott Jenkins

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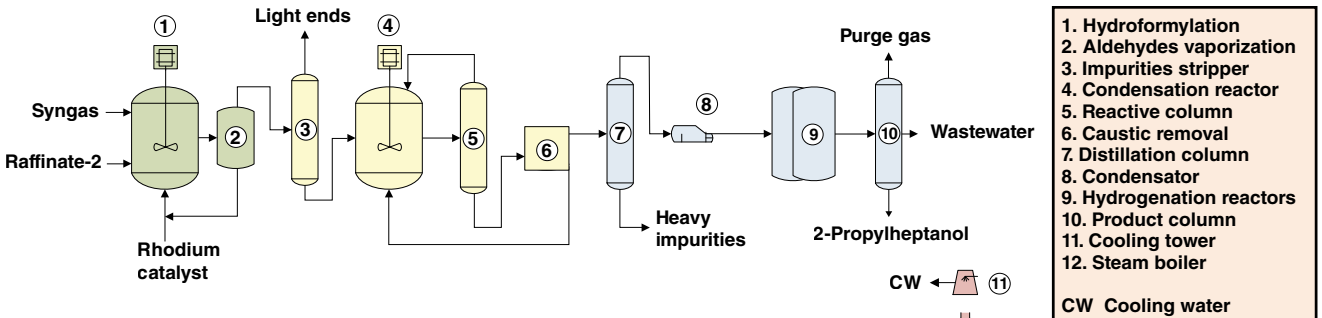

FIGURE 1. The diagram shows the production of 2-propylheptanol via Oxo synthesis

Part 1

Create An Analytics-Enabled Workforce

New self-service data analytics tools allow plants to create an analytics-enabled workforce that can readily address production issues and continuously improve processes

Edwin van Dijk
TrendMiner

IN BRIEF

TrendMiner

FIGURE 1. Specialty chemical companies need to find data-analytics-driven ways to sustain their market position

The specialty chemicals sector of the chemical process industries (CPI) is highly complex, from both a production and a market standpoint. Smaller batches (with a finite quantity) coupled with an ever-changing variety of raw materials, operating conditions and processes can present huge challenges to production teams. Increasing operating costs and a competitive market amplify those challenges. To maintain a solid market position, companies need to find new ways to remain innovative, sustainable and competitive (Figure 1).

One way to do so is by increasing financial flexibility to safeguard against commoditization. This can be done by getting as much out of existing production capacity as possible. In a market where growth is continuing, and rolling out new products is becoming more and more difficult, sustainability is crucial.

The production teams that will undoubtedly have a leg up will be the ones embracing the emerging technologies that have stemmed out of the rise of Industry 4.0. They are realizing the value that digitalization can bring when they are fully able to leverage the volumes of data at their disposal — on their own, without the need for a data scientist.

These forward-thinking organizations in the specialty chemicals market are turning to solutions like self-service analytics to create an analytics-enabled workforce, not only to strengthen their market position and create the most profitable factories of tomorrow, but to address critical production issues and make better-informed decisions.

When the information hidden in the data is properly connected to the knowledge in the minds of subject-matter experts (SMEs), an organization can finally move toward a proactive, data-driven process improvement strategy. Within the area of specialty chemicals, this means a digitally enabled workforce can efficiently increase throughput and quality by solving daily analytic challenges themselves, which leads to increased operating efficiency overall and a stronger market position.

All of the data in the world are meaningless if they are not being analyzed and acted upon. With self-service analytics, there is no need to create a cost-intensive data model. Its plug-and-play functionality and user-friendly interface means your organization can begin creating value immediately with minimal investments. Insights into a process and asset behaviors are based on a wealth of historical and real-time data that your plant already owns.

This article explains how self-service analytics approaches democratize the use of data analytics and provide real-world examples of

how plants have used self-service analytics to improve batch processes.

All data tell a story

As with any niche market, working within specialty chemicals comes with its own specific targets and areas that organizations have to focus on and continuously improve upon. Increasing throughput, lowering energy consumption, and reducing non-productive downtime are just a few of the things that are important to a production team. However, achieving these goals is a much harder feat if all the available data is not being leveraged.

Decades of time-series data for thousands of sensors in a large production facility is overwhelming. Sifting through it using traditional methods is nearly impossible and many opportunities to potentially improve operational performances are overlooked. Spreadsheets will always be a staple in terms of office software, but as a tool for aggregating and analyzing data, it simply isn't enough.

In order to quickly make decisions affecting their day-to-day operations, engineers and other SMEs need to be able to search time-series data over a specific timeframe and visualize all related plant events quickly and efficiently (Figure 2). Additionally, a level of operational intelligence and understanding of data is required to improve process performance and overall efficiency.

As the amount of accessible data for producers and manufacturers continues to grow, it is only natural that new ways to handle data are needed. The rise in digitalization is less about providing pro-

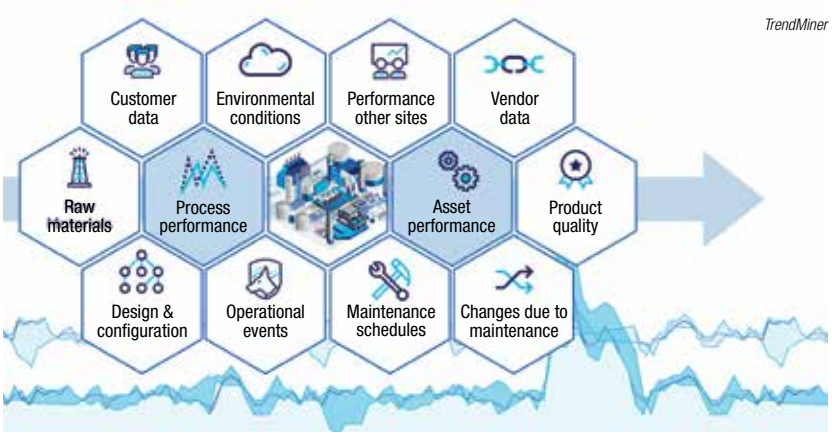

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FIGURE 2. To help with decision-making, engineers need to be able to visualize all related plant events quickly and efficiently. Data tell more stories when data silos are unlocked

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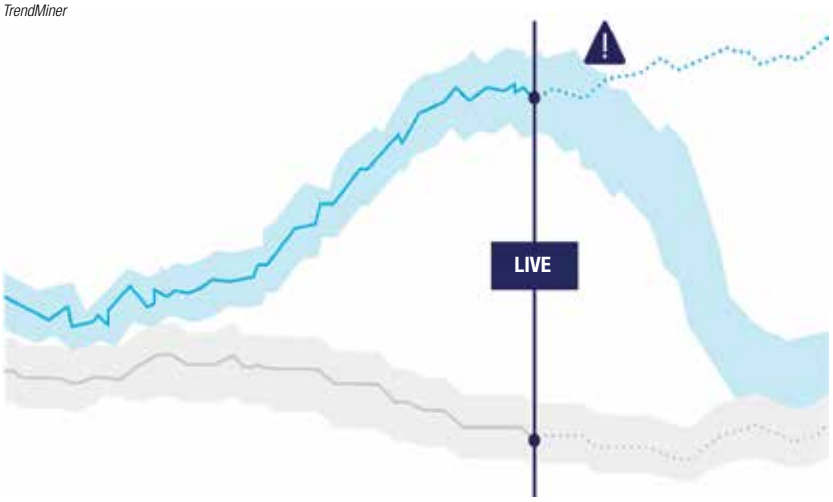


FIGURE 3. Rapid-fire pattern recognition predicts future operational behavior, allowing timely action. Pre-described suggestions allow subject matter experts to take appropriate actions on notifications they receive

duction teams with new tools, but rather new ways of working and executing day-to-day operations. Advanced analytics can be used by CPI companies to monitor production, address complex issues, and extract information on assets and processes without lengthy data-modeling by analytics experts.

So whether you are looking to reduce cycle time, find the root cause of a quality deviation, or predict the evolution of your batch, you will need to go through your sensor-generated time-series data. And if you find yourself consistently in a reactive stance with your analysis to keep the plant running, you could be missing opportunities for proactive process improvements.

Democratizing analytics

Data analytics is a necessary part of any organization that wants to measure and track operations and make informed decisions. Business consulting firm Gartner (www.gartner.com) lists four different types of analytics. These four types generally grow in complexity, but all serve a purpose within the analytics value chain.

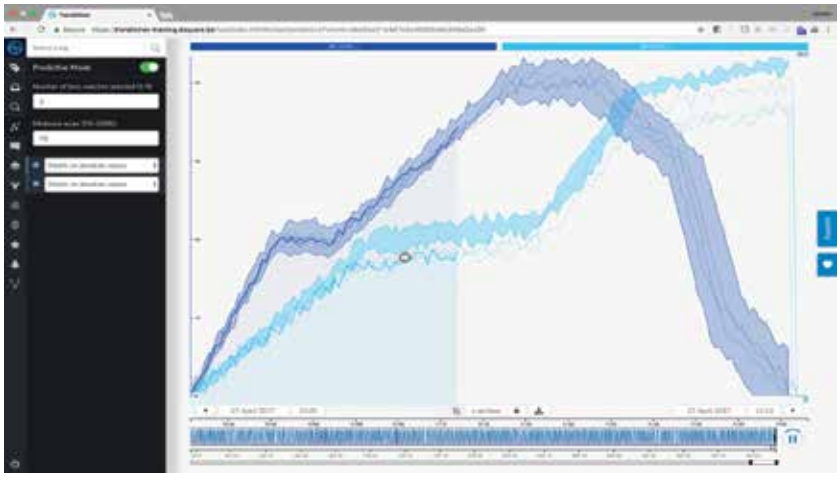
Descriptive analytics: What is happening in my operations? This type of analytics is the most common and perhaps the simplest, but nonetheless vital. It provides the insights and key metrics needed to visualize and understand your operations. Think of descriptive analytics as the "who, what, when, where, how and how many" of basic reporting. With self-service analytics, engineers can visualize their operations to fully understand what is happening at all levels.

Diagnostic analytics: Why is this happening in my operations? Diagnostic analytics is just as it sounds: it is used to uncover why an event occurred and then determine the root-cause of the problem. This is a particularly useful form of analytics when dealing with time-series data because it helps you understand the cause and effect between various data sources, as well as identify patterns. With a pattern recognition-based self-service solution that is responsive and intuitive, process data can be analyzed and interpreted. That is the key to closing the analytics skill gap and bringing advancements to where it matters: the process experts.

Predictive analytics: What will happen in my operations? Predictive analytics takes things a step further. This form of analytics uses your data — and the findings from descriptive and diagnostic analytics — to predict specific outcomes based on trends and dependencies. Predicting anything from equipment failure to production evolution, predictive analytics allows you to make decisions that could have giant impacts in your operations. Historically, the only way to predict the behavior of batch processes had been by building complex data models. These models are difficult to build, costly to maintain, and the results are hard for process experts to easily interpret. New approaches (such as self-service analytics) are available that are fast and iterative, easy to interpret and robust. Process experts using self-service analytics can now tackle predictive analytics independently, which can lead to, among other things, debottlenecking central data-science departments.

Prescriptive analytics: What do I need to do in my operations? This final form of analytics takes all of your data, in-

FIGURE 4. Self-service analytics can be used to effectively visualize, analyze, monitor, contextualize and predict operational performance



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sights gathered and trends produced, and determines potential future courses of action. Prescriptions require a good diagnosis, so it often comes down to pre-described suggestions that allow the SMEs to take appropriate actions on the notifications they receive, and the instructions provided by the system (Figure 3). With every new situation, knowledge expands for fast and appropriate action when early warnings are sent or needed action is predicted by the system. We call this user-driven machine learning. In a very complex specialty chemical environment with small batches, this is crucial.

Within a chemical plant, any or all of the aforementioned analytics are necessary in order to address the issues and goals that production teams are facing. Traditionally, data scientists have been required in order to solve complex issues. Having to rely on data scientists or central analytics teams to create data-driven solutions or resolve any data analysis-related questions, however, can lead to missed opportunities that can be costly in terms of time and money.

So how exactly does the plant engineer, maintenance engineer, safety engineer or production engineer go about analyzing data without traditional models? This can be done by enabling the masses, so that not only analytics specialists, but the vast majority of a company's employees can utilize the data. That means making business intelligence (BI) and analytics tools accessible to business users and SMEs so they can analyze the data and derive new insights just by using their particular expertise, without needing to acquire sophisticated analytics skills.

This is best described as the democratization of analytics. And there is actually no better way to implement that than using self-service analytics.

Self-service analytics explained

Self-service analytics leverages smart data combined with the tactical expertise of those at the production site. It puts the power of the data into the

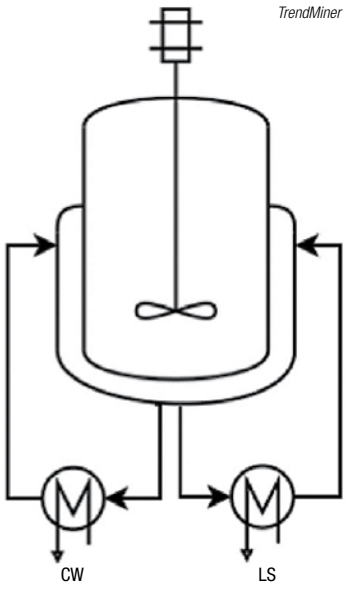

FIGURE 5. Self-service analytics helps predict heat exchanger fouling, and control the process to avoid it

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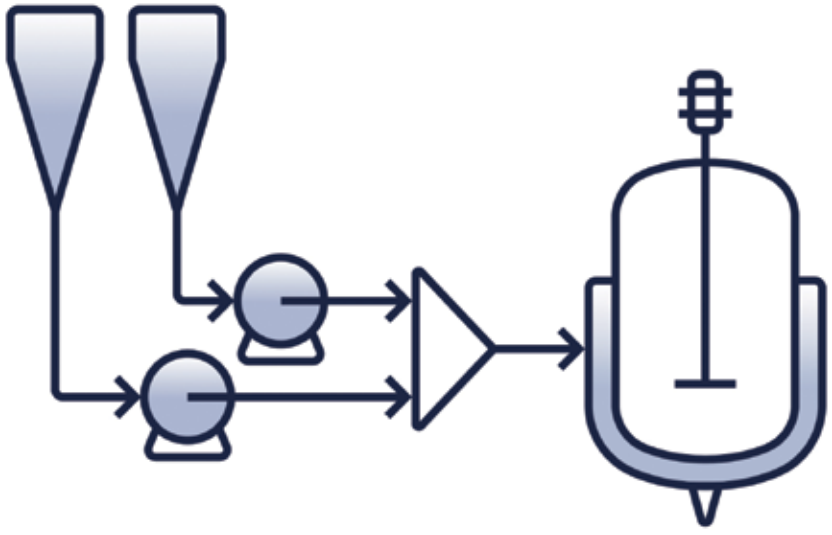

FIGURE 6. Self-service analytics can allow engineers to quickly find the root cause of a process problem and adjust batch cycle time, for example

hands of those who really need to interpret it (Figure 4).

All four types of analytics, from descriptive to predictive, can now be performed by operators and engineers. Besides visual analytics, self-service analytics software can provide various tools, filters and advanced queries to find anomalies, create early warnings and troubleshoot incidents across multiple assets. For example, an incident during production may seem like a single occurrence, but with rapid-fire pattern recognition technology, it may turn out that the incident has happened multiple times over the past few years.

Engineers investigating potential process optimizations may start by searching for specific anomalies in process behavior. Searching for tags is as easy as searching in Google where easy time sliders and filters help you navigate through years of data. The first question is "what has happened?" directly followed by "has this happened before?". If multiple occasions are found, the engineer can start searching for root causes using either influence factors or a recommender engine.

Additionally, periods of best performance can be collected and overlaid to create fingerprints (for the process) or best operating zones (for the assets) that can be used as monitors. The monitors can be used to capture events, while events reside in other third-party business applications, such as maintenance management or laboratory information management systems. All this can lead to new starting points for process optimization, leading to a continuous-improvement loop through data analytics and contextualization of operational production data.

Building a production cockpit

Ideally, all operational stakeholders would have what we refer to as a "production cockpit" to work with that is complete with a dashboard, analytics suite and agile communications facility. Users can create and share complete and live overviews of their current process statuses and performances, enabling teams and individuals to immediately access production data, analyze situations at hand, and make decisions in an instant.

When you enhance the current process status overview with the early-warning capabilities that self-service analytics solutions provide, the production cockpit can provide operators the opportunity to be proactive and optimize operational performances, even before issues arise. It also helps optimize the flow of information between shifts, from shift teams to engineers and between all related actors and production stakeholders, thereby boosting the organization's collaborative agility. These are just a few of the ways that self-service industrial analytics is able to cater to the needs of engineers today.

Real-world use cases

Predicting fouling of heat exchangers. In a reactor with subsequent heating and cooling phases (Figure 5), the controlled cooling phase is the most time-consuming, and it is almost impossible to monitor fouling when the reactor is used for different product grades and a different recipe is required for each grade. Fouling of heat exchangers increases the cooling time, but scheduling maintenance too early leads to unwarranted downtime and scheduling too late leads to degraded performance, increased energy consumption and potential risks.

Under normal process conditions, self-service analytics can be used to identify a general trend for predictive-maintenance planning, alert and support a maintenance decision, and help find the right process parameters to tweak in order to lengthen the time between maintenance cycles. However, fouling can also be caused by other factors — the viscosity of the process fluid changed, the temperature of the heat-

transfer fluid changed, and others. In this situation, self-service analytics can be used to diagnose and prevent these specific fouling cases by detecting the root cause (that is, process anomalies upstream), and used to predict when engineers need to be alerted.

In one instance in the production of a polymer, a specialty chemicals company used a visual trend analysis to determine the influence factors of the fouling that was occurring. To enable a timely maintenance, a monitor was set up to look at cooling times of the company's most highly produced products. If the duration of the cooling phase started to increase, a warning would be sent to the engineers, who could then get maintenance scheduled.

Self-service analytics allowed the engineer to set this up in less than an hour, and it ultimately resulted in extended asset availability, reduced maintenance costs, reduced safety risks and controlled energy consumption. All of these benefits ultimately led to more than 1% overall revenue increase of the production line, while maintaining stable product quality.

Yield increase through cycle-time reduction. A specialty chemicals company produces specialized fibers that are subject to strict quality constraints. The final performance of the process is measured through metrics such as cycle time, end product quality and yield.

Gradually over time, the production of the fibers began to run suboptimally. Recent batches were taking longer to complete, which led to increased cycle times. Despite previous optimization efforts, plant engineers were unable to identify and address the cause of these cycle-time delays.

Through a simple set of steps using a self-service analytics platform, the team quickly identified the best batches from five years of operational data. These batches were layered with recent suboptimal batches, which revealed a key optimization opportunity (Figure 6).

First, the team used a value-based search and filter functionality to find all relevant batches. Next, they sorted the

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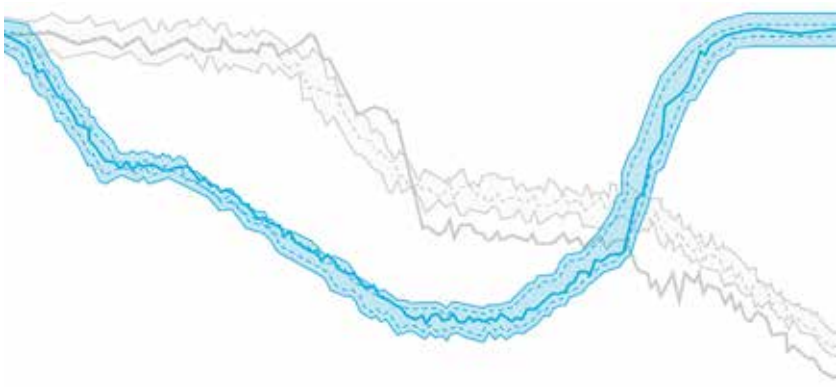

FIGURE 7. Use best-performance fingerprints to monitor performance and avoid production stops

results by duration to identify the production batches with the highest yield and shortest cycle time. From there, engineers layered approximately 15 ideal batches from a 5-year period where a visual comparison of the layers revealed their ideal "golden batch" profile (Figure 7). The final step consisted of overlaying 10 recent batches on top of the golden batch profile created in the previous step. Immediately, a clustering became apparent. Midway through the full batch cycle, the recent batches significantly deviated from the historically best performers.

Subject matter experts could immediately recognize that this was related to a change in the ramping up of a raw material feed. Material was being added at a slower rate compared to historical golden batches. They were able to determine that increasing the raw material feedrate would allow them to revert back to their previous performance and reduce their cycle time.

The engineers had been faced with increased cycle times for quite a while, leading to tangible production and revenue losses. Leveraging the analytics capabilities of a plug-and-play solution, the root cause was identified, and a solution could be developed. The improvement potential was around 30 minutes on a 9-hour batch cycle, which translated to an estimated $1 million per year in business value. The engineers were able to do all of this in four hours.

Additional examples

Reduce emissions by improving off-gas treatment. A chemical company was experiencing problems during off-gas treatment. With data from their data historian, combined with search and discovery analytics, they were able to do a hypothesis check quickly and easily. Confirming their hypothesis enabled the team to decrease problematic situations with off-gas treatment by 63%, and by doing so, greatly reduce emissions as well.

Production quality optimization. In this case, a team at a chemical plant was experiencing a poor-quality production run for which the root cause was not clear. The team used self-service analytics software to compare good quality periods with bad quality periods in production runs. Through the software's layer compare feature, they were able to easily identify what caused the problem. It helped them to ensure high quality production runs in the future.

Eliminate a potential production loss. Process engineers at a chemical facility were experiencing unwanted production stops. By tagging good batches as "fingerprints" they were soon able to identify deviations in production runs, leading them to a problem in the control system. Finding the root cause with fingerprints helped them eliminate a potential production loss of 125 tons, or almost $300,000.

Energy monitoring without spreadsheets. Energy monitoring is an important factor when addressing sustainability. In the past, one chemical company would use Excel files to manually compare energy consumption data from one year to another. Self-service analytics now allows the engineers to easily bring a certain year into focus. By adding the following years of energy consumption as layers, they are able to easily compare large periods of time without needing to use Excel. ■

Edited by Scott Jenkins

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Part 2

Advanced Analytics: Accelerating Insights for Engineers

The surge in data volumes within the chemical process industries has made it difficult for engineers to find the insights they need to improve processes. Advanced analytics applications enable engineers and others to harness the data for improved operations

Michael Risse
Seeq Corporation

IN BRIEF

Every day, the chemical process industries (CPI) produce data at an unprecedented rate, including historian-based process data, and business and manufacturing system contextual data. Plants can generate terabytes of sensor data per day, and companies can generate scores of terabytes of data per day. With the rise of sensors and other equipment connected via the industrial internet of things (IIoT), these data volumes are expanding exponentially.

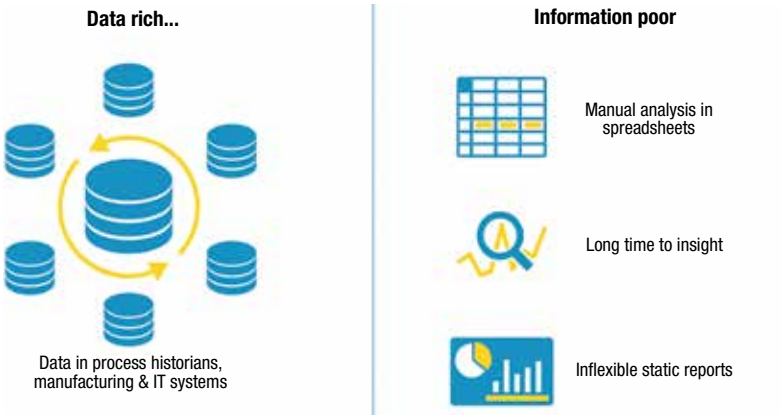

FIGURE 1. Many CPI plants and facilities are data rich, but information poor, driving the need for new advanced analytics solutions

And, the problem of too much data and too little insight will only accelerate as IIoT takes hold. IIoT forecasts correlate to the amount of data generated, and the International Data Corporation (IDC) is expecting worldwide spending on IoT to reach $745 billion this year, led by the manufacturing sectors [*1*]. That represents a massive increase in sensor data. Despite the hype around "smart" sensors, the data will go to waste absent robust analytics to enable insights.

In fact, "data rich, information poor" (DRIP), threatens to drown organizations in a sea of underutilized data (Figure 1), driving a search for new solutions. For the last 30 years, spreadsheets were the analysis tool of choice in process manufacturing, but this general-purpose tool is no longer sufficient for complex analysis of the expanding volumes of time-series data.

At all levels of the manufacturing enterprise, from operators to engineers to field staff to quality control, and up to the executives, everyone needs useful insights for daily decision-making. And they need self-service access to data without the need for assistance from information technology (IT) experts and data scientists. Fortunately, a solution is at hand in the form of advanced analytics.

Improved solutions for analyzing data

A new class of analytics applications leverages new technologies, including big data and machine learning (ML) innovations, to accelerate engineers' time to insights. Advanced analytics applications cover the crucial "last mile" between data and insights, enabling employees in many different roles to do their own analysis and share their findings in the moment, without the required intervention of a data scientist or other IT expert.

FIGURE 2. Advanced analytics empower engineers to interact directly with the data of interest to quickly drive insights and improve outcomes

A number of compelling scenarios come into focus with the use of today's advanced analytics. For example, as explained in more detail in a subsequent section of this article, predictive analytics on equipment can warn of impending failure so operators can take action to prevent an unplanned event. In one example, accurate batch-cycle-time analysis helped to focus process improvement efforts, which shaved off 10 minutes of total batch time and led to an annual production increase of 300 batches. In another example, management received near real-time alerts about commodity pricing, enabling them to make decisions which boosted plant profitability.

These improvements are not only within reach, but are achievable today with the use of advanced analytics applications. Furthermore, chemical processors can now realize significant benefits without needing to implement an expensive and time-consuming digital transformation initiative, because advanced analytics integrate new capabilities into existing operational technology (OT) environments and can connect with cloud offerings for greater agility.

This is a welcome development for CPI companies, which have been quick to embrace the cloud, especially for analytics workloads. The benefits of a cloud deployment model are clear: faster time to solution, an elastic infrastructure that can grow and shrink with ease, greater agility and reduced complexity. That said, cloud deployment is not a requirement for advanced analytics deployments, and many users either choose, or are tethered to, on-premise deployments.

A taxonomy for analytics

Analytics per se is nothing new, but advanced analytics is, and it accelerates the outcomes for all the different types of analytics applied in process manufacturing:

- *Descriptive analytics* describes what happened, using reports, charts and key performance indicators (KPIs) based on collected data, all of which may be shared in near real time
- *Monitoring analytics* tracks asset, batch or operations performance and seeks to answer the question "what is happening now?"
- *Diagnostic analytics* seeks to identify why some-

FIGURE 3. This screen shot shows how advanced analytics was used to cut CIP cycle times and reduce energy use

thing happened based on analysis of historical data, often called root-cause analysis

- *Predictive analytics* helps engineers identify what will likely happen based on real-time and historical data, enabling corrective action to be taken in advance
- *Prescriptive analytics* aims to optimize outcomes by informing plant employees of their best actions based on existing conditions

The benefits yielded by advanced analytics applications are not speculative, but are instead being realized today by chemical manufacturers to improve outcomes, including increased efficiencies, boosted quality, better visibility, increased agility and higher profit margins. Once advanced analytics is placed in the hands of plant engineers and other experts (Figure 2), improvements quickly follow, as shown in the following examples.

Applications

Speeding batch cycle times. For a large specialty chemical company, a small improvement in the cycle time of a batch process often results in huge financial improvements. In one case, a company had a process that produced 10 batches per day, with a cycle time per batch of 2.4 hours or 144 minutes, resulting in 3,640 batches per year. The engineering team used advanced analytics for current-state analysis and "what-if" modeling, identifying optimizations that shaved 10 minutes off of each batch. The new rate was 10.7 batches per day, or 3,912 batches per year, almost 300 additional batches from what at first glance appeared to be just an incremental improvement.

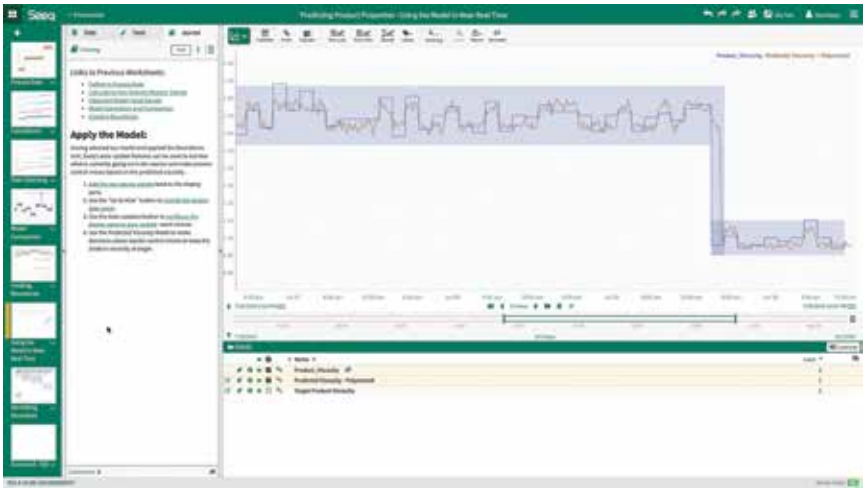

FIGURE 4. This model allows engineers to predict product properties to forestall product quality issues

In the past, cycle-time analysis required an engineer to review past batches to determine the slowest or most variable phases of the process. Specifically, an engineer looked at a spreadsheet of numbers and dates instead of a trend. After creating "phases" with a start and end trigger for one batch, an engineer would make manual adjustments until the desired batch construct was determined.

Defining these start and stop triggers was exceedingly tedious with spreadsheets, and more manual work would then be required to apply this analysis against additional batches for more detail. Excessive time and work were required before an engineer could find the best cycle times and implement the changes required to realize those incremental gains across all batches.

Now, during regular daily meetings, operations personnel are able to quickly analyze batches produced yesterday, compare the cycle times to the best time, and, if necessary, quickly investigate why the cycle times were slow or variable. The results of these investigations are then used to improve the process, with actions typically taken within hours, instead of after weeks of spreadsheet-based analysis.

Optimizing clean-in-place cycles. Clean-in-place (CIP) is a technique often used by specialty chemical companies to avoid contamination from one batch to the next when switching among different product types. Because no product can be produced during a CIP cycle, it is imperative to reduce the time it takes to complete cleaning.

Figure 3 illustrates how an advanced analytics application was used to optimize CIP cycles by focusing on the critical process parameters, which, in this example, are conductivity of the cleaning fluid, along with fluid flow. The first step is definition of the CIP phases using data drawn from the batch historian or event database. Once the phases are defined, Step 2 adds conductivity and flow signals to the display. The engineer then performs Step 3 by searching for times with a positive value for flow combined with low conductivity. A condition is then created for instances when flow is above a defined threshold and conductivity is below another defined threshold.

Overcleaning is then identified, in Step 4, as times when flow is above threshold and conductivity is low. Step 5 shows potential utility savings by calculating total flow during periods of overcleaning. The final step is to create a scorecard with KPIs to show potential utility savings, along with reductions in CIP cycle times by minimizing periods of overcleaning.

Improving quality. Beyond boosting efficiency, the use of advanced analytics can go right to the heart of a CPI company's most important performance indicator: quality. In one case, a large-scale specialty

chemical manufacturer needed to ensure tight control of finished-product properties, which corresponds to product quality, and ultimately profitability.

Most companies in the industry, including this one, control the finished product properties based on feedback from laboratory results received some hours after material is produced. If a predictive model could be developed to reliably and accurately forecast the product properties based on conditions in an upstream part of the process, the company could make process adjustments in near real time, minimizing margin loss from product downgrades.

Using advanced analytics, company engineers built a model to predict product quality excursions (Figure 4). When these events were detected, engineers were able to quickly adjust the process to improve quality.

Using the model for near real-time quality control, rather than relying on traditional feedback methods based on laboratory results, the company reduced product margin losses by more than $1 million annually.

The analytics advantage

The surge in data volumes within the CPI is increasing the difficulty of finding insights. Yet the pressure to find insights and be "analytics-driven" is higher than ever, placing demands on plant executives and process engineers alike.

Insights that take too long to discover languish because they cannot easily be published and shared with others. Advanced analytics applications address these and other issues by connecting with data from a wide array of sources to surface insights much more quickly in a format that is easy to share, enabling actions to improve business results and profitability.

Advanced analytics bridge the gap between the glut of process data and the engineers who need the insights. Advanced analytics enable engineers, operators, executives and other team members to do their own analysis in the moment, enabling breakthrough improvements. ■

Edited by Dorothy Lozowski

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Part 1

Seal Selection: Ensure Regulator Performance in Low-Temperature Applications

In low-temperature conditions, the use of compatible sealing materials is essential for leak-tight operation and proper functionality of pressure-regulating devices

Jon Kestner
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IN BRIEF

Harsh, frigid conditions are among the most challenging industrial environments (Figure 1) for fluid-handling applications. At these temperatures, it is especially difficult to ensure proper, leak-tight operation of fluid-system components. Elastomeric sealing materials inside components can harden, crack and simply stop performing when temperatures drop too low. Therefore, at extremely low temperatures, valves, regulators and many other components may not fully seal, causing leaks. Additionally, the components may become difficult, if not impossible, to actuate.

FIGURE 1. Industrial facilities in cold climates face a host of challenges when it comes to preventing fluid leaks

Ensuring sound low-temperature performance can be especially difficult within dynamic fluid-system components like pressure-reducing regulators (Figure 2), which are commonly found in many gas-supply applications. When such applications take place in northern climates like those found in Alaska, Canada, Siberia, northern Europe and the Arctic Ocean where temperatures may dip to –40°F (–40°C) or colder, sensitive regulator components can become less responsive as temperatures drop. If engineers and operators do not specify the appropriate materials of construction for the regulator's sealing elements, onsite technicians may need to constantly tend to the components, which can be tough to manage in frigid conditions.

Beyond the challenges of operating in cold environments, pressure-reducing regulators can also create low-temperature conditions of their own when regulating gas pressure. As a regulator reduces the pressure of a gas, the gas can lose significant heat due to the thermodynamic relationship of pressure and temperature — a phenomenon known as the Joule-Thomson effect. The temperature drop may be so drastic that the regulator ices over. The regulator's sealing elements will need to perform reliably in this situation to ensure both sealing and operation.

To confirm that a regulator will deliver leak-tight sealing and function properly at extremely cold ambient temperatures, engineers and operators must carefully choose sealing materials that meet the lowest tem-

peratures anticipated during service. They should also ensure that the regulator manufacturer has tested the regulator at low temperatures using those materials to avoid any surprises.

Regulators in cold conditions

Common low-temperature regulator applications include industrial- or bulk-gas supply configurations that are located outdoors. Such systems may supply large volumes of gas or liquefied gas to a facility, with the liquified gas first being converted into a gas via vaporization. Such gas supplies are generally located outside of facilities for safety reasons, as well as for delivery logistics, so that tanker trucks can easily refill the gas cylinders or bulk tanks outdoors. The cylinders, tanks and associated gas lines are not typically climate-controlled, meaning that components can be exposed to the elements. Exposure to extreme temperatures can affect regulator performance in two ways: their ability to seal properly; and their ability to control pressure effectively.

Sealing mechanisms within regulators are most often made of various elastomeric materials. Such materials are prone to shrinking and hardening as temperatures drop. As a result, the elasticity the materials exhibited at warmer temperatures diminishes, making it more difficult to create a positive seal. At colder temperatures, the elastomers deform barely, if at all, when making contact with sealing elements, such as the poppet or diaphragm inside a regulator. This reduces their sealing ability. Furthermore, at low temperatures, the elastomers may even reach their glass transition temperature (T_g), at which point they become especially brittle. The resulting hard surface may no longer provide a positive seal. In either case, system fluid may escape past the shrunken, hardened sealing materials and either escape to atmosphere or creep across the regulator's seat from the high- to low-pressure areas of the regulator under no-flow conditions.

The functionality challenges that a low-temperature operation presents for regulators is also related to elastomeric hardening. As elastomers stiffen, it can be more difficult for dynamic elements within a regulator to move freely. It may therefore be difficult for the regulator's poppet to move out of its valve seat as pressure demands call for this action. Any slow response may cause system flow through the regulator to become restricted. In addition, downstream pressure may drop further than desired, or at least be inconsistent as the regulator's sensing element attempts to react to system changes while encountering restricted movement.

The best way to address the limitations that low-temperature conditions present to regulator performance is to select elastomeric sealing materials that can withstand

the lowest temperatures anticipated during operation. In addition, the lubricants applied to sealing mechanisms should be chosen for reliable operation in cold temperatures.

Pressure drops effect cooling

Environmental conditions aside, regulators that are used to reduce gas pressure face the risk of experiencing drastic cooling through the course of their normal operation due to the Joule-Thomson effect. When a gas is forced through a narrow opening to reduce its pressure, such as what occurs within a pressure-reducing regulator's seat, the gas temperature will drop drastically on the downstream side where the gas expands. This is true for all real gases, except helium, hydrogen and neon (unless the real gases reach their inversion temperature point, at which they get hotter during expansion, instead of cooling down). Conversely, most liquids will warm up when passing through the same constricted flow path.

With the Joule-Thomson effect, the temperature change of a gas is proportional to the amount of pressure drop on the downstream side of the regulator. Depending on the pressure drop, the temperature drop experienced when throttling a gas could be so severe that the regulator itself will ice over. Exterior ice can form around the regulator's low-pressure outlet connection as moisture from the surrounding air condenses on the metal. Ice can also form inside the regulator's bonnet, and any ice buildup there can prevent free movement of the regulator's sensing elements, including its spring and diaphragm, or sealing elements, such as the the piston or poppet. Regulator icing can occur even at warmer temperatures, but it presents a greater threat to regulator performance in low-temperature environments, because the regulator's internal components are more likely to become restricted in extremely cold conditions.

FIGURE 2. Various regulators can perform reliably in extremely low-temperature conditions when engineers specify the appropriate materials of construction for the regulator's sealing elements

To mitigate freezing on both the inside and outside of a regulator,

FIGURE 3. One option to mitigate regulator freezing as a result of the Joule-Thomson effect is to heat the process lines using heat tracing

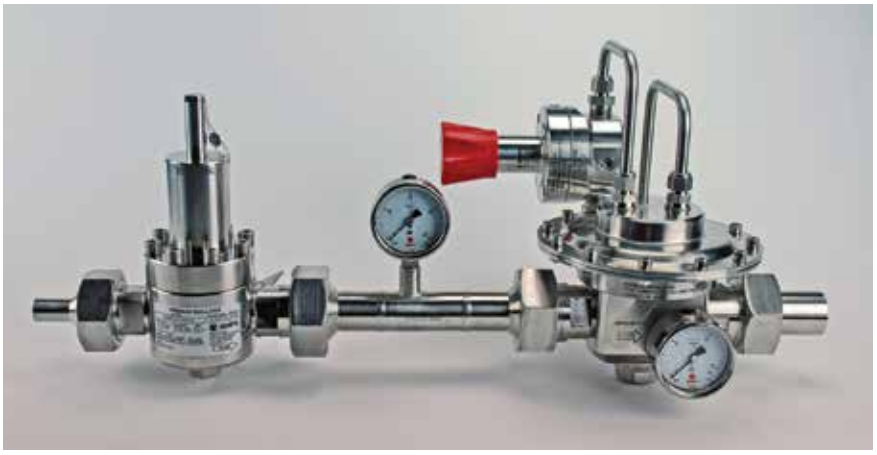

FIGURE 4. Reducing gas pressure in two stages, as shown in this configuration, can also help to mitigate the Joule-Thompson effect

plant engineers can arrange to heat the process line or even the regulator. Process line heating may involve placing heat tracing or insulation on lines (Figure 3). Alternatively, a heated enclosure can be installed around the regulator. When doing so, engineers must account for the higher heat when selecting sealing materials for the regulator to ensure that the materials will not deform from the additional heat.

Another option to mitigate the Joule-Thomson effect is to reduce the gas pressure in two stages using a two-stage regulator setup (Figure 4). In such a system, the first pressure regulator would handle the majority of the pressure drop and cooling, while the second pressure regulator would manage the fine control. This type of setup can be tuned to avoid icing in many situations, but rarely in conditions where ambient temperatures are extremely cold.

Just like the strategy for enhancing regulator performance in cold temperatures, the solution to addressing issues related to Joule-Thomson effect cooling is to choose regulator sealing materials that will perform at low temperatures. Doing so will minimize leak potential and help to ensure regulator operation.

Selecting sealing materials

When operating regulators, any cooling — whether due to ambient temperature drops or internal thermodynamics — that dips below the performance temperature limit of the regulator's elastomer sealing materials increases the likelihood that the regulator will not seal properly during operation. Therefore, operators must carefully select materials of construction for all of a regulator's sealing mechanisms, which may include the following: the seat seal, which seals high inlet pressure from reaching the low-pressure side of the regulator; dynamic seals, such as where the regulator's poppet seats into its body; seals for sensing elements, such as elastomeric diaphragms or piston O-ring seals; and any static seals that seal the regulator components together to contain

internal pressure (Figure 5).

Within a regulator, any of the aforementioned seals could be made of an elastomeric material, such as butyl rubber, fluoroelastomer (FKM), nitrile rubber or a wide array of other materials. However, diaphragm sensing mechanisms may sometimes be made from polytetrafluoroethylene (PTFE), and seat seals may sometimes feature harder materials like polychlorotrifluoroethylene (PCTFE) or polyether ether ketone (PEEK).

Elastomers are rubber-like polymers that maintain flexibility above their T_g temperatures, enabling positive sealing in a wide range of applications. Below their T_g, elastomers become brittle and can even crack or break, potentially causing sealing failures. As elastomers cool, they also shrink. The process is known as temperature retraction (TR). When considering appropriate elastomers for low-temperature service, component manufacturers typically focus on the material's tested TR-10 limit, which designates the point at which the elastomer has retracted, or shrunken, 10% after being stretched and frozen according to testing protocols. This point is a preliminary indicator of the material's lower-temperature limit and can be used when making sealing material selections. As an elastomer approaches its TR-10 limit, it begins to behave more like soft plastic than rubber, but should still maintain reliable positive sealing. As the material cools further, it approaches its T_g temperature, at which point it may no longer maintain a seal because it has hardened too much to deform at sealing contact points.

Selecting an appropriate elastomer for low-temperature regulator applications will depend on the lowest temperature limits anticipated for the component's service. For example, when anticipating outdoor temperatures of –40°F, operators may opt to use nitrile seals, as the material has been confirmed to perform at this temperature via laboratory testing. Nitrile is a good choice because it is a popular elastomer that performs well in low temperatures, and many compounds of nitrile are compatible with a wide range of applications, including low-temperature service for applications containing hydrocarbon mixtures. Numerous other options are available, but operators will need to verify the low-temperature performance and chemical compatibility of those materials based on the application. For example, ethylene propylene diene monomer (EPDM) also works well at low temperatures, but may not have acceptable chemical compatibility with hydrocarbons.

Verifying sealing performance

Installing a regulator for low-temperature service should not represent a risk for a chemical plant, petroleum refinery or other operation. Therefore, despite confirming the low-temperature performance

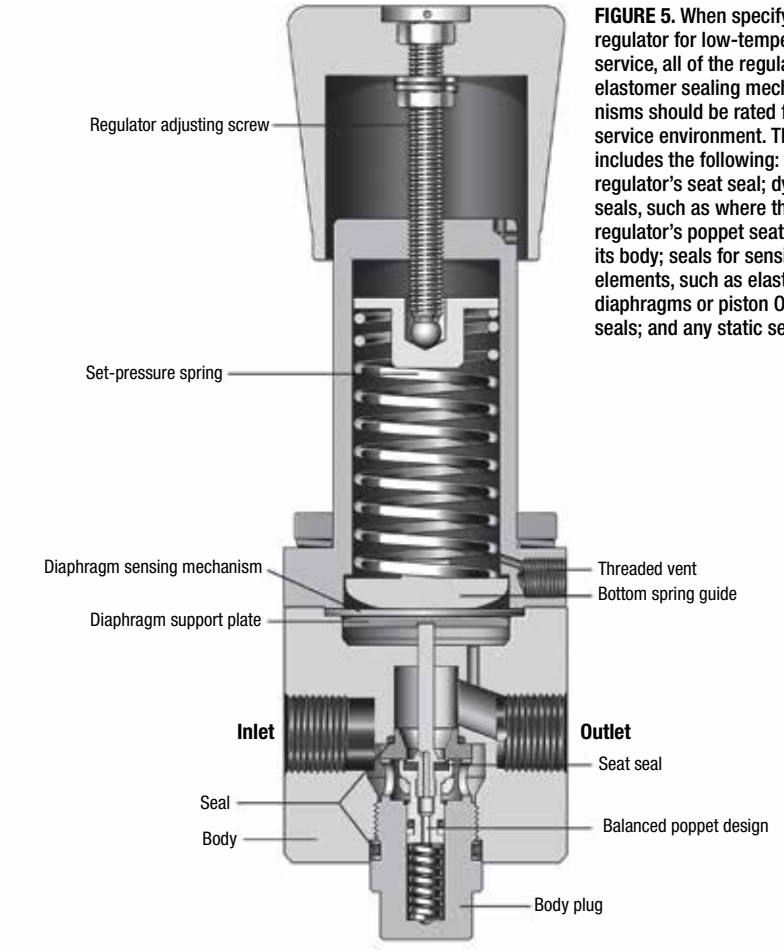

FIGURE 5. When specifying a regulator for low-temperature service, all of the regulator's elastomer sealing mechanisms should be rated for the service environment. This includes the following: the regulator's seat seal; dynamic seals, such as where the regulator's poppet seats into its body; seals for sensing elements, such as elastomeric diaphragms or piston O-ring seals; and any static seals

of an elastomer based on charts developed from laboratory testing, it is advisable for those materials to be tested within the actual components in which they will be used. Without performing leak and functional tests, the manufacturer — not to mention the operator — cannot know if the regulator will deliver the expected results.

A regulator manufacturer should perform various tests using a particular material to help verify the anticipated real-world performance of the component. The testing should be robust enough to confirm not only that the regulator will seal and not leak at very low temperatures, but that the regulator will also operate (control pressures) at those temperatures.

Testing the regulator's sealing capabilities can be accomplished via the following two common tests:

Seat leak test. By applying low and high pressures to a regulator at extremely low temperatures, the manufacturer will be able to determine if the regulator's sealing elements are able to fully seal and not allow pressure and system fluid to escape to the outlet side under no-flow conditions — a phenomenon known as creep.

Shell leak test. With the regulator's internal components energized, manufacturers can test the component at extremely low temperatures to confirm that no internal pressure is leaking to atmosphere.

These two tests could be considered "seal and survive" tests, as they can prove that a material is able to provide a sufficient leak-tight seal at reduced temperatures. It is helpful for such tests to include a series of temperature cycles — going from room temperature to low temperature or high temperature several times — to confirm how the material reacts to fluctuating temperature stresses. Simply testing the material one time at a cold temperature does not necessarily prove its performance.

While these tests are helpful to verify a regulator's sealing performance, they do not provide insight into how the regulator will actually perform at low temperatures. While the regulator may seal sufficiently at –40°F (–40°C), for example, it may have a high actuation torque — or not be able to actuate at all — because the elastomeric O-ring surrounding the poppet is too stiff to move. The act of actuating the regulator at a low temperature may even damage sealing surfaces, creating leaks. Therefore, manufacturers should expand their testing protocols to also include functionality testing.

For functional testing, manufacturers should test components under various temperature cycles, as well as pressure cycles. Temperature cycling accomplishes the same goals as in sealing testing — to verify performance based on fluctuating temperatures. Testing functionality at various pressures is important because a leak at a low pressure may seal at a higher pressure. It is important to know if this may occur so that operators can anticipate this possibility in the field.

Operators should select regulators and sealing materials carefully to ensure that their components can be used across a broad range of temperatures and pressures, and will not just "seal and survive" in cold climates and applications where significant cooling occurs due to high pressure drop, but also perform reliably in those conditions. ■

Edited by Mary Page Bailey

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Part 2

Pump Sealing for Hazardous Chemicals

Pumping hazardous chemicals requires specific shaft-sealing technologies to ensure containment and reliability

Michael Kalodimos
John Crane, Inc.

IN BRIEF

Hazardous chemicals are defined by the Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) as those that are potentially harmful to human health and the environment. Existing as gases and liquids, they are manufactured, stored, transported and used throughout the chemical process industries (CPI). Handling toxic chemicals, such as ethylene oxide, toluene, butadiene, methylene chloride, xylene and scores of other acids and hydrocarbons, requires equipment that ensures process reliability and material containment. Central to this machinery are pumps, which must reliably move fluids and gases through every stage of processing.

Transporting and pumping hazardous chemicals requires a complete knowledge of their physical properties. Pumping complex chemicals like butadiene, for example, requires special attention to chemical composition, as well as the transmission mechanism and the hydraulics involved. For example, butadiene presents an extreme explosion and fire hazard when permitted to reach its vapor point (Figure 1), and has extremely rigorous requirements for its storage and handling (Figure 2). Like many other hazardous chemicals, butadiene must be refrigerated and maintained under pressure. Faults in its handling will result in pump flow restriction and a host of related operational difficulties.

Failure of pumps and other rotating equipment in industrial processes can have dire consequences, jeopardizing environmental, health and safety (EHS) conditions at the plant. Although mission-critical equipment is typically redundant with spare pumps and spare piping, unplanned failure is extremely costly and exposes the plant to periods of un-spared operation. This increases risk and interrupts regular preventative-maintenance procedures followed elsewhere in the plant. This article examines pump-sealing ideologies for hazardous materials.

FIGURE 1. Butadiene is a crucial part of countless end products, but its hazardous nature makes it very difficult to handle and transfer without the proper combination of pump and sealing technologies

Pump seals for hazardous chemicals

Pumps handling volatile and hazardous chemicals are carefully specified, along with suction and discharge piping, to provide consistent flow and maintain a high level of control. Hazardous chemicals pose significant challenges to pump performance, and specifically to the operation of a pump's shaft-sealing system. The transmission of hazardous fluids demands a sealing system and sealing technology that operates effectively while avoiding emissions to the atmosphere.

Pump seals are engineered to operate with specific hazardous chemicals, under known parameters of abrasive conditions, pressure changes, extreme temperatures and multi-phase fluid properties. Seals are vital to maintaining pump efficiency, reliability, energy consumption and control of emissions to the environment.

Air-quality surveys conducted in chemical plants have determined that the majority of a site's toxic-release inventory is attributable to the shafts of centrifugal pumps. Historically, the performance of mechanical shaft seals and the sealing technology specified has had a major effect on the toxic-release survey results for a given operation. In recent years, advanced controls and the popularity

FIGURE 2. Butadiene is often stored in specialized spherical vessels that maintain the proper pressure and temperature to ensure safe and reliable processing

FIGURE 3. Pumps that handle hazardous materials can be equipped with non-contacting dry-gas seals to improve fluid transfer and safety

of dual seals and dual non-contacting gas seals have played a major role in reducing the toxic-release totals at chemical manufacturing plants and petroleum refineries. Two very different emissions-abatement strategies have been applied to fluid transmission in recent years: sealless pumps, and non-contacting, dry-running dual-gas seals.

Sealless pumps

On the heels of the Clean Air Act of 1990, and amendments to the act implemented by local air-quality boards, the answer seemed to lie in pumps that did not rely on conventionally driven impellers. Magnetically coupled pumps or "sealless" pumps enjoyed significant interest from a large segment of the conventional ANSI pump market. The absence of a mechanical coupling theoretically eliminates any leak path between the flooded pump volute and the electric motor drive.

Two types of sealless pumps are common: canned motor pumps and magnetically driven pumps. Canned motor pumps have the windings of the electric motor built into a hermetically sealed pump body. The pump shaft and impeller are driven by a rotor winding affixed directly to the shaft. This rotating shaft is supported by bearings and surrounded by the motor's stator winding. All of these components are hermetically sealed into a can, which forms the pump. Motor windings are cooled, and bearings are lubricated by the fluid being pumped.

Magnetically driven pumps rely on a conventional electric motor to drive a set of magnets. The driven magnets, in turn, transfer torque to a set of opposite-pole magnets that drive the pump's impeller. The pump shaft's magnets operate in the pumped fluid, and are hermetically sealed. Again, shaft bearings are lubricated by the fluid being pumped. The product flows through lubrication and cooling ports integral in the pump head design.

As a result of this approach, a trend developed where magnetically coupled pumps were applied wherever emissions were a potential problem. After baseline air-quality surveys found emissions levels to be out of compliance, decisions were made to limit penetrating shafts, resulting in a significant investment into magnetically driven, sealless pumps.

Conceptually, in sealless pumps, the product being pumped must assume two new roles: that of the heat-transfer fluid; and as the bearing lubricant. Unfortunately, the product being pumped does not often possess the lubricating and heat-transfer properties required to properly support the magnetically coupled equipment. This can lead to significant maintenance problems associated with sealless pumps.

The bearings of a magnetically driven pump are typically made of inert, non-metallic materials — often ceramic or silicon carbide. Of course, any bearing is intolerant of lubrication loss, but silicon carbide is particularly unforgiving of dry-sliding contact. The absence of adequate liquid volume can quickly lead to critical damage of bearings and bushings, and high repair costs. Brief seconds of dry running can result in immediate bearing failure, which is often catastrophic. In such events, impeller alignment is lost, and frequently the containment shell of the pump is in danger of rupture. Even where lubrication is thought to be adequate, hydraulic requirements of the system can place demands on thrust surfaces, wear rings and bearings that are beyond the capabilities of the process fluid. This can result in unplanned failure and increased risk of containment rupture.

The application of magnetically driven pumps requires a thorough understanding of their hermetic technology, as well as a precise familiarity with the fluid being moved. Some modern magnetically driven pumps apply ceramic containment shells to serve as the can containing the drive elements of the magnetic coupling. This strategy has been applied to combat problematic eddy currents and localized wear that can occur with conventional alloy canisters.

Non-contacting dry-gas seals

Introduced in the 1980s, non-contacting, dry-gas seals have become standard in the industry for pump seals handling hazardous chemicals.

Spiral-grooved dry-gas seals are non-contacting, dry-running mechanical face seals that consist of a mating ring and a primary ring. Typically, the grooved face (mating ring) is stationary and the ungrooved primary ring is rotating. Seal arrangements vary, and often there are requirements for the ungrooved face to remain stationary.

In either arrangement, a spiral groove pattern will compress an inert gas to produce a hydrodynamic lifting force, allowing the stationary face to separate and operate with a small gap, which is effectively lubricated by the inert gas that serves as a barrier fluid. In recent years, dual non-contacting gas seals have featured spiral grooves at the inner diameter (I.D.) of the seal face. The inboard seal is pressurized on the I.D. with barrier gas. The arrangement differs from conventional outer-diameter (O.D.) pressurized gas seals. This arrange-

ment can further enhance the behavior of the seal by placing the liquid being sealed at the O.D. of the faces, effectively eliminating the possibility of de-watering and drying of the process fluid. Process fluid drying and de-watering, as well as changes in viscosity, which can happen with conventional dual seals, are a significant root cause of failure.

Non-contacting dry-gas seals typically use an inert barrier gas supplied at roughly 25 psi above stuffing box pressure. Barrier gas is supplied as a dead-headed source of inert gas. When the shaft is not turning, the spring-energized seal faces contact the un-grooved portion of the mating ring, effectively forming a static seal.

Non-contacting seals are gas lubricated. The barrier gas provides a stiff lifting force to both primary rings of the seal, eliminating contact and, as a result, friction. Spiral grooved non-contacting seals generate virtually no heat. The double seal arrangement and pressurized barrier gas offer a zero-emissions solution, while maintaining product purity. These seals are suitable for use in harsh working environments that must handle hazardous chemicals (Figure 3).

No emissions, increased uptime

Pumps that handle hazardous chemicals are subjected to the rigors of abrasive conditions, pressure changes and extreme temperatures, and therefore, can be prone to axial movement over time, a condition under which many seal designs can fail.

Dry-gas seal designs that incorporate a rotating mating ring are better able to tolerate radial movement and imperfect pump-shaft excursions over time. Ultimately, a non-contacting gas seal does not develop a wear pattern. This delivers a more tolerant seal and results in significantly improved uptime when compared to sealless pumps.

Of considerable importance where non-contacting dry-gas seals are applied is the preservation of product purity. Often, the product stream is finished or nearly complete. Additionally, product streams can be sensitive to seal lubricants and barrier or flush liquids. Examples of ultra-high purity requirements include special polymers, food and flavor ingredients and even water that is used for intravenous injection. Preserving product purity is a key driver, and often eliminates filtration and costly liquid-extraction activities. ■

Edited by Mary Page Bailey

Editor's note

Read the online version of this article at www.chemengonline.com for an additional case study on pump-sealing strategies for butadiene handling.

Author

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IPCO Germany

Brabender Technologie

Amandus Kahl

K 2019, known as "The World's No. 1 Trade Fair for Plastics and Rubber" and scheduled to take place in Düsseldorf, Germany from October 16 to 23, is fully booked. Over 3,000 exhibitors from more than 60 countries have registered to participate. K will occupy the entire Düsseldorf exhibition grounds with some 175,000 m^2 of net exhibition space. More than 200,000 trade visitors from all over the world are expected come to the event.

"Plastics for sustainable development" and the "circular economy" are among the hot topics touched on at the exhibitors' stands, as well as being covered comprehensively in the supporting program. For example, the special exhibition "Plastics Shape the Future" also sees itself as a podium for solutions and answers to current social trends and discussions. Topics to be discussed include packaging waste, marine litter and climate change, as well as resource conservation, energy efficiency and recycling.

Organized by Messe Düsseldorf, the K show takes place every three years. Further information is available at www.k-online.de.

A small selection of products being exhibited follows below. More can be found in the online version of this preview at www.chemengonline.com.

Technology for manufacturing composites

Previously operating as Sandvik Process Systems, this company is making its first appearance at K 2019 as an independent company within the Swedish Wallenberg group. The company manufactures solid and perforated steel belts used for improving productivity and quality in the processing of products as diverse as wood-based panels, film, floorings, advanced composites and more. Its Composite Solutions division designs, manufactures and installs systems for the production of a wide range of composite materials used across many industries, including automotive, aerospace, flooring, construction, non-wovens, textiles and many others. These include press systems used for impregnation, lamination and consolidation, a full range of upstream/downstream equipment, including precision scattering systems. Within its portfolio is the ThermoPress range of double belt presses — a modular system that enables multiple stages to be incorporated into a single efficient process — and the ScatterPro family of precision scattering systems (photo). Typical applications for these systems are pressing, lamination, impregnation, cooling and scattering. Hall 12, Stand 12/E19 — *IPCO Germany GmbH, Göppingen, Germany*
www.ipco.com

Re-engineered feeders, and much more, exhibited here

The DSR28 (photo) and DDSR20 feeder models have been completely re-engineered. In addition to a new type of gearbox, this new range features many new components that are all compatible with one another and allow easy operation without tools for easy cleaning. Both machines will be exhibited, along with the possible motor types, such as the new motor with extended adjustment range (1:100). Other highlights include the new FiberXpert fiber feeder for lower feedrates; a FlexWall 40 with acrylic plastic container that can be controlled with a mobile device using a web server application; an unusual version of a feeder with twin screws based on special user requirements; the DS feeder range for granulate matter; liquid feeder and a feeding channel; and more. Hall 10, Stand A41 — *Brabender Technologie GmbH & Co. KG, Duisburg, Germany*
www.brabender-technologie.com

Processing polymer additives with this pelleting press

The polymer industry uses a great variety of additives. They are used to stabilize polymer structures, to prevent damage to the final product by heat, shear energy and oxidation, for pigmentation and for ultraviolet (UV) protection. Many of these additives are already processed on Kahl flat-die pelleting press (photo). In the flat-die pelleting press, the pan grinder rollers rotate on a horizontally arranged flat die (disc die). They press the product from above in the axial

direction through the bores. Materials, dimensions, surface profile and number of rollers can be varied according to product and throughput. The press is available from laboratory scale up to production capacities of more than 1 ton/h. The pellet diameter is typically 2–3 mm. Hall 10, Stand H08 — *Amandus Kahl GmbH & Co. KG, Reinbek, Germany*
www.akahl.de

A new, improved rotary filter for polymer melts

This company will exhibit several different models of its patented rotary filtration systems. These continuous filtration systems are characterized by a filter disk on which the screen cavities are located in a ring pattern. Screens can be changed on the part of the filter disk that is not active in the melt channel, while the production process continues to run without any interruptions or disturbances. The new model SFneos (photo) was developed to combine the characteristics of several older models into one simple and cost-efficient solution, offering the following advantages: constant pressure guaranteed, even during screen changes; suitability with most types of polymers and viscosities; compact design, thanks to an enlarged active screen area (up to 2,370 cm^2); simple and safe handling and operation with several screens accessible for screen changes; and cost effectiveness, thanks to its improved design. Hall 9, Stand A38 — *Gneuss Kunststofftechnik GmbH, Bad Oeynhausen, Germany*
www.gneuss.com

Highly scalable paperless recorder with intuitive operation

The Logoscreen 700 (photo) is a new model from this company's paperless recorder series. It is highly scalable in terms of measurement input and output cards, so that it can be adapted flexibly to different applications. These equipment options range from a device version without measurement input to versions with a maximum of 18 measurement inputs, three analog outputs, 18 digital inputs, 24 individually switchable digital inputs and outputs, and seven relay outputs. Through a PROFINET interface, up to 60 analog and digital channels can be recorded, as well as 120 external analog and digital inputs displayed. The device also has up to eight counter inputs, which facilitate flow measurement based on fast digital-pulse generators. Hall 10, Stand H34 — *JUMO GmbH & Co. KG, Fulda, Germany*
www.jumo.net

New generation of strand pelletizers for improved quality

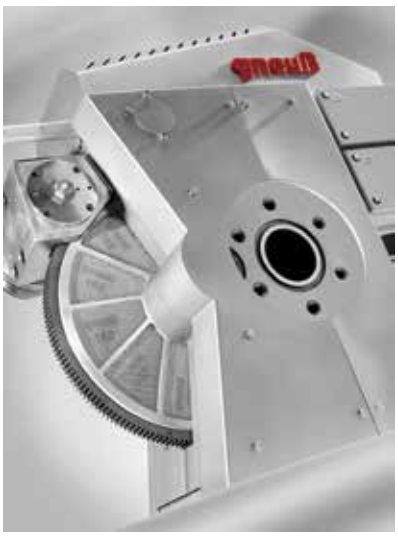
This company is introducing improved dual-bearing strand pelletizers (photo), which have been re-engineered based on field experience and current market demands. The SP140, SP240 and SP340 models in the SP series have been equipped with a variety of enhanced features for easy, rapid handling and optimized pellet quality. Moreover, the company has developed a new proprietary technology for cutting-gap adjustment. This patent-pending cutting-gap adjustment constitutes the heart of the re-engineered strand pelletizers. Hall 14, Stand B19 — *Coperion Pelletizing Technology GmbH, Offenbach, Germany*
www.coperion.com

Systems expertise together at one stand

For the first time, all of this group's companies will be exhibiting together at the K Show, featuring all their system solutions. The company is presenting new and upgraded machinery for pumping, filtration, pelletization and pulverizing technology. Its portfolio extends from small machines and systems for throughputs up to 100 kg/h, to machine and plant components capable of handling more than 100 ton/h (centrifugal dryers, polymer pumps and custom solutions in industrial applications). The experience within the group extends across virgin polymer production, compounding, extrusion, mechanical end-of-life recycling of plastic products and highly engineered industrial pump applications. The company will also be represented in Hall 16 in the VDMA's Circular Economy Pavilion. Hall 9, Stand A04 — *Maag Group, Oberglatt, Switzerland*
www.maag.com

Gerald Ondrey

Gneuss Kunststofftechnik



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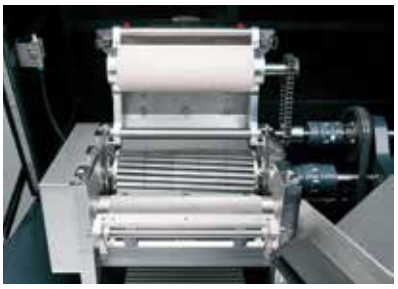

Coperion Pelletizing Technology

Air Movers for Dilute-Phase Pneumatic Conveying

Selecting the best air mover for a bulk-solids pneumatic-conveying application is a critical design decision. Provided here is information on three classes of air movers when dilute-phase pneumatic conveying is required

Gary Liu
DuPont

In a typical bulk-solids pneumatic-conveying system, an air mover is used to generate the necessary air flowrate and pressure required to transport a solid material through a specific pipeline distance at a given rate. Designing a successful pneumatic conveying system depends on specifying the correct air mover, in terms of volumetric flowrate, pressure and motor size. A wide range of machines is potentially capable of meeting the requirements of the duty. However, not all air movers are suited to pneumatic conveying applications. Therefore, understanding the design and operating characteristics of various air movers is the key to successfully selecting the right machine.

This article discusses the operating mechanisms and characteristics of three different types of air movers for dilute-phase pneumatic conveying: centrifugal fans and blowers; regenerative blowers; and positive-displacement (PD) blowers. Numerous air movers are available on the market for dilute-phase conveying applications. In many cases, two or even three types of air movers can perform the same job, delivering the accurate amount of air flow at the correct pressure. However, their capital investment and operation costs, as well as machine efficiency and reliability, will certainly be different. Understanding their mechanisms of operation can assist in choosing an effective air mover for the successful design and operation of any pneumatic conveying system.

Air mover types and uses

A European Union study has shown that 15% of the world-wide energy consumption is used to produce compressed air. The typical air movers — fans, blowers, and compressors — are widely used in various industries, such as agriculture, energy, mining, chemical production and others. Air movers typically used for pneumatic conveying applications include centrifugal fans and blowers, regenerative blowers, PD blowers and PD compressors. The air mover is often the largest single item of capital expenditure in a pneumatic conveying system, and the potential conveying capacity of the system is mainly dependent upon the air mover selected.

FIGURE 1. Centrifugal fans, such as the one shown here, are one possible option for use in a pneumatic conveying application

Centrifugal fans and blowers produce high volumetric flowrates at low pressures, usually for conveying systems with very low solids-to-air ratios, such as dedusting and milling. PD blowers produce medium volumetric flow rate at medium pressure, accounting for over 80% of pneumatic conveying installations, typically for dilute-phase systems. PD compressors, usually reciprocating or rotary-screw machines, can produce the highest pressures required for long distance or dense-phase conveying systems. Regenerative blowers are a niche air mover, which can provide small flowrates at low to medium pressure in a very cost-effective way.

Table 1 lists the types of air movers that are used for pneumatic conveying applications and their characteristics, such as compression mechanism, air flow and pressure ranges.

All air movers are similar in that they are moving and compressing air through internal chambers (a PD blower is different, because its air is compressed at the discharge port, not in the internal chamber). For the purposes of specifying an air mover for pneumatic conveying, air can be treated as an ideal gas, which obeys the equation of state:

$$\rho = P / RT \quad (1)$$

where P is pressure; ρ is density; R is the gas constant per unit mass; and T is temperature.

Centrifugal blowers and fans

Centrifugal blowers and fans are aerodynamic-type air movers and are widely used on short-distance, very dilute-phase systems. The solids-to-air ratio for a fan conveying system is typically less than 1.2 to 1. If its feedrate is steady and smooth, the solids-to-air ratio can be up to 2 to 1. Fans may be used for both positive-pressure and negative-pressure conveying systems. The centrifugal fan/blower used in pneumatic conveying applications, are normally of the radial, flat-bladed type, similar to the one shown in Figure 1. At a given speed, these centrifugal fans or blowers will draw the same volume of air at a given pressure.

The basic function of a centrifugal fan/blower is to produce kinetic energy by the action of centrifugal force. Its impeller and channels convert this kinetic energy of the air into potential energy (in the form of pressure) by efficiently reducing the velocity of the flowing air. For example, a fan with a wheel diameter of 30 in., running at 3,000 revolutions per minute (rpm), has an impeller tip speed as high as 23,562 ft/min, which leads to a velocity pressure of 34.62 in. H_2O (inches of water column). If the ultimate fan air-outlet velocity is 4,000 ft/min, the total kinetic energy converted to potential energy is 33.62 in. H_2O.

Figure 2 shows the operating characteristics of centrifugal fans and blowers. The air flowrate is highly dependent upon the conveying-line pressure drop. If the solids feedrate to the system should become excessive for any reason, causing the system pressure drop to increase significantly, the air flowrate becomes so low that the material falls out of suspension. This increases the risk of blocking the pipeline. Because the residence time of the material in the conveying pipeline is very short, a sudden surge in feed rate can quickly have a significant effect on the pressure required. Therefore, centrifugal fans and blowers can only be used for applications with low pressures and low solids loading, and cannot be used reliably for heavy-duty conveying. Steady and controlled material feed can minimize feed surge and ensure a reliable centrifugal fan/blower operation. Due to this airflow-pressure relationship, centrifugal fans/blowers may not recover from emergency shutdown when conveying solids.

TABLE 1. COMPARISON OF AIR MOVERS FOR PNEUMATIC CONVEYING

	Mechanism	Inlet capacity, actual ft^3/min	Maximum discharge pressure / vacuum	Operating speed, rpm	Maximum power, hp
Centrifugal fan/ blower	Dynamic	60 – 250,000	14 – 128 in. H_2O column	800 – 3,800	1,600
Regenerative blower	Dynamic	40 – 900	13 psig 14 in. Hg	2,000 – 4,500	120
Rotary lobe blower	Positive displacement	15 – 30,000	5 – 25 psig 18 in. Hg	300 – 4,000	500
Rotary screw compressor	Positive displacement	120 – 58,000	15 – 700 psig	1,000 – 20,000	8,000

The relationship between fan power and system pressure drop is also shown in Figure 2. As pressure decreases, the power increases. This is because at low pressure, the fan has to move a large amount of air, which consumes a lot of power. This is also why sometimes operators must choke-start a fan to minimize the power drawn when a small motor is installed. The lowest power drawn happens when the system pressure is the highest. Therefore, centrifugal fans and blowers are unloaded by closing either the inlet or the outlet.

Fan performance curve

The fan performance curve (Figure 3), is the most valuable information supplied by fan manufacturers. These curves show the relationship

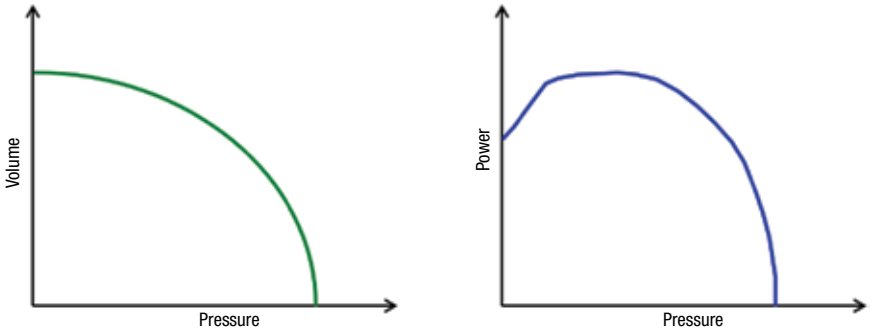

FIGURE 2. The plots show the operating characteristics of fans (left) and blowers (right). Air flowrate is highly dependent upon conveying line pressure drop

between the air volume that a fan will deliver, and the pressure generated at various air volumes. The curves also show power for a given air volume. A system resistance curve is always included, and this usually is associated with a specific fan application. The system resistance is the sum of all pressure losses through the pipeline, including all pipeline elbows, filters, dampers and any other element that resists flow. The fan will operate at the point where the system resistance curve intersects the fan curve.

For some fan curves provided by fan manufacturers, there is a fan surge curve (the circle in Figure 3). Selecting fans such that they operate close to, or to the left of, the surge curve, is not recommended. Referring to this surge curve helps the designer to ensure selecting fans that are stable and will not go into surge with a minor change to the system.

The fan brake horsepower can be found from the power curve in the fan performance diagram. By using the calculated system pressure drop and required air flowrate, you can also estimate it according to the following equation:

$$BHP = P \times Q / 5{,}085 \quad \textbf{(2)}$$

where *BHP* is the fan brake horsepower (hp); *Q* is the fan flowrate (ft^3/min), and *P* is the fan operating pressure, (inches of water column). Equation (2) gives an approximate value of the fan motor power required. For example, in the previous case, if air flowrate is 11,000 ft^3/min, the *BHP* for the fan is about 43.26 hp.

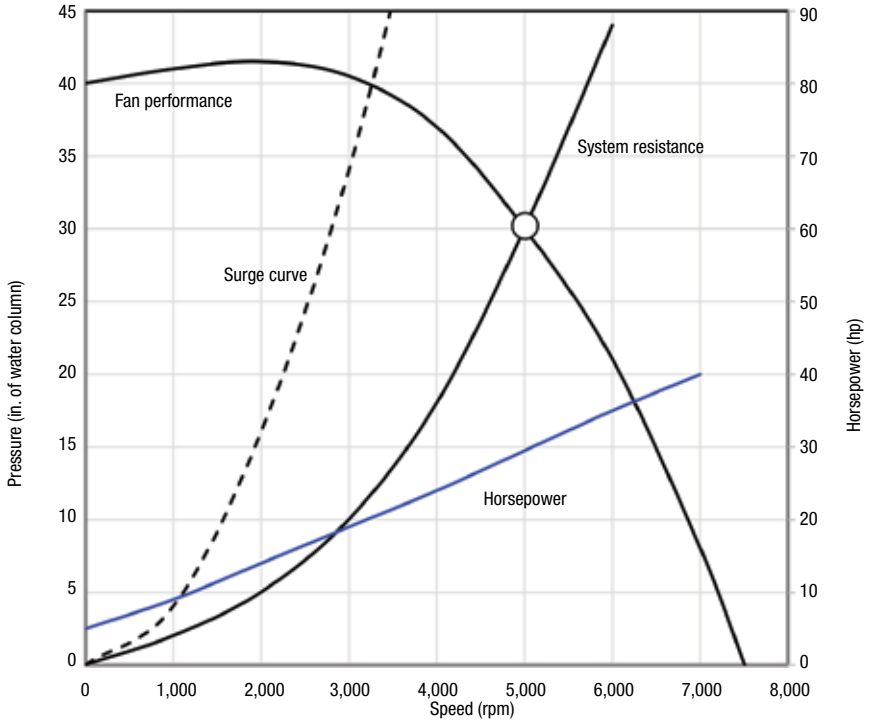

FIGURE 3. Fan performance curves, such as the one here, shows the relationship between the air volume that a fan will deliver, and the pressure generated at various air volumes

Fan laws

There are two reasons why a fan's performance may need to be changed:

- The system requires additional airflow
- The actual system resistance pressure is different from the design value

When these situations occur, it is important to understand how they can affect the fan's performance. The effect can be shown by using the Fan Laws, shown by Equations (3a), (3b) and (3c).

$$Q_2 = Q_1 \times (N_2/N_1) \quad \textbf{(3a)}$$
$$P_2 = P_1 \times (N_2/N_1)^2 \quad \textbf{(3b)}$$
$$BHP_2 = BHP_1 \ (N_2/N_1)^3 \quad \textbf{(3c)}$$

where Q_1 and Q_2 are the fan volume, ft^3/min; P_1, P_2 are the fan operating pressure, inches water column; and BHP_1 and BHP_2 are the fan brake power, hp.

For example, a fan installed in a conveying system running at 1,500 rpm is to handle 15,000 ft^3/min at 16 in. water column and 45 BHP. What fan speed is required to move 20% more air, or 18,000 ft^3/min, through this system? What is the new fan operating pressure and fan BHP? Using the fan law equations above, we obtain the following:

- N_2 = 1,800 rpm
- P_2 = 23.04 in. water column
- BHP_2 = 77.76 hp

Therefore, according to the fan laws, in order to use the original fan, its speed must be increased from 1,500 rpm to 1,800 rpm, and the BHP increases 72.8%, from 45 hp to 77.76 hp. Thus, with a 20% air flowrate increase, the motor must be upgraded from 50 to 100 hp. Of course, make sure the new speed value is less than the maximum allowable speed for the existing fan.

Temperature and altitude effects

In each fan catalog, the performances tables are based on standard air density, which is defined as dry air at 70˚F at sea level (29.92 in. Hg barometric pressure). This is equal to 0.075 lb/ft^3 density. The fan performance tables provide the fan speed and brake power requirements for the given volumetric flowrate value and static pressure, at standard air density.

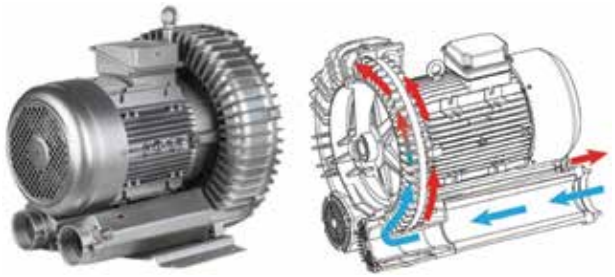

FIGURE 4. Regenerative blowers are used with low airflow and medium pressure

When the fan performance is not at standard conditions, the performance must be converted to standard conditions before using the fan performance tables. The fan must be selected for the given rate of flow, but for an equivalent static pressure. The equivalent static pressure is the working static pressure corrected for temperature and altitude. The fan performance is converted to standard conditions by either using the correction factors in the temperature and altitude correction chart, which are usually included in fan catalogs, or by dividing by the calculated correction factors: temperature factor = the ratio of standard absolute temperature (°R) to working absolute temperature (°R); altitude factor = the ratio of barometric pressure at the given elevation to that at sea level (29.92 in. Hg), or the ratio of the density reduction factor shown in some tables.

To illustrate, we can use the same example as mentioned previously, but now assume that the fan is operating at 300°F and 4,000 ft elevation above sea level. In this case, what are the fan speed and the motor size? Since this fan is not operating at standard conditions, we cannot use the fan performance table directly. The 16 in. static pressure has to be corrected by both the temperature and altitude factors. The temperature factor is 0.697 (= 530°R/760°R) and the altitude factor is 0.864 (= 25.84 in. Hg/29.92 in. Hg).

The equivalent static pressure, therefore, becomes the following:

$$P_{equivalent}$$

$$26.566 \text{ in. } H_2O \quad \textbf{(4)}$$

Now we can use the fan performance in Table 2 to interpolate the fan speed at 1,845.698 rpm and the brake horsepower at 76.934 hp. The brake horsepower at the working static pressure would be corrected as follows:

$$BHP_{real} = 76.934 \times 0.697 \times 0.864 = 46.355 \text{ hp} \quad \textbf{(5)}$$

A 50-hp size motor would be enough for this job. However, if the fan were operated with cold air, the horsepower drawn, 66.443 hp (= 76.934 × 0.864), would exceed the capacity of the motor and the airflow to the fan would have to be throttled until the equipment warms up to the correct temperature.

If a centrifugal fan/blower is used for vacuum-conveying, negative static pressure exists on the inlet side of a fan, and an additional correction for a lower density should be made. When negative pressure is less than 20 in. water column, this factor (called rarefication factor) is usually considered negligible, unless the system designer is calculating to extremely close tolerances. The factors apply to static pressure and brake power in the same manner as temperature and altitude corrections. You can find the rarefication factor either in fan catalogs or by using the following formula: rarefication factor = the ratio of working absolute pressure to standard absolute pressure.

Actually, all of the corrections are based on the inlet density changes due to various temperatures and pressures (altitude, inlet vacuum). The changes are reflected from the assumed ideal gas in Equation (1).

FIGURE 5. The exterior (left) and interior (right) of the twin-lobe Roots blower are shown here

Regenerative blowers

The regenerative blower is also an aerodynamic-type air mover, and is mainly used on short to medium distance, dilute-phase systems, such as drum/bag dump stations and solids conveying eductors (Figure 4). The solids-to-air ratio for a regenerative blower conveying system is typically less than 4 to 1, and its

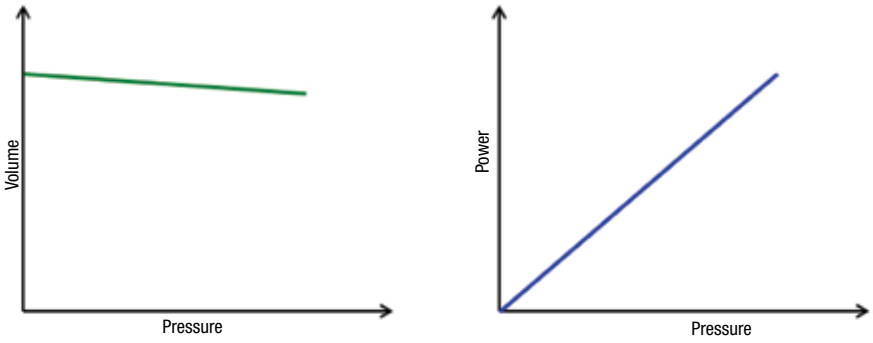

FIGURE 6. The graphs show operating characteristics of PD blowers, which deliver a practically constant flowrate, independent of disharge pressure conditions

maximum air flowrate is about 900 ft^3/min. Regenerative blowers have parallel inlets and outlets that are positioned perpendicularly to the rotation of the impeller. Regenerative blower installations are typically in a direct-drive design, as shown in Figure 5. However, it can also be a belt-drive design. The impeller in the direct drive construction is mounted directly on the electric motor.

Regenerative blowers have a slightly different mechanism than centrifugal fans/blowers for compressing air. The impeller consists of numerous radial blades along the circumference of the impeller. The impeller spins within a housing that consists of an inboard and outboard "channel." As the impeller passes the inlet port, air is drawn in. As the impeller rotates, air is captured between each blade on the impeller and is pushed both outward and forward into the channels. The air then returns to the base of the blade. During this process, a portion of the kinetic energy (air velocity) is converted to potential energy (air pressure). This process is repeated over and over as the impeller spins. While each blade-to-blade regeneration "stage" results in only slight pressure increases, the sum total, from air entry to outlet can yield continuous operating pressures of up to 13 psig or vacuum to 14 in. Hg.

Performance curves for regenerative blowers are generally better than those shown for the centrifugal fans and blowers shown in Figure 3, but are not as good as those for positive-displacement machines. In other words, its air flowrate is less dependent upon the conveying-line pressure resistance. Therefore, it can be used for higher-solids-loading applications than a centrifugal fan/blower.

Among the most significant benefits of a regenerative blower is that it is virtually maintenance-free. There is only one moving part (the impeller), which does not come in contact with the housing channel and is essentially wear-free. Regenerative blowers can operate for up to 40,000 hours without requiring service — a properly installed regenerative blowers is capable of providing years of service-free operation.

Regenerative blowers are oil-free and have no complicated intake/exhaust valve. They can be mounted in any plane and, with dynamically balanced impellers, generate little vibration. As a non-positive displacement compressor, the discharged air, like centrifugal blowers, is pulsation-free, and therefore, generates extremely low noise. Even without an acoustical cover, the typical free field noise level is only 82 dBA at 3 ft distance.

Due to the tight internal tolerances between the impeller and housing, it is important that foreign material not be allowed to enter the blower. A filter, such as a 10-µm filter, should always be installed before the inlet of a regenerative blower.

Overpressurization can also cause a catastrophic failure. Most blowers must have air passing through to cool it. Without it, heat will build up, causing the impeller to expand at a faster rate than the blower housing. If this continues, the impeller will eventually lock up with the housing and cause the blower to fail. A relief valve (either vacuum or pressure) will prevent overpressurization and will allow air to pass through the blower.

Positive-displacement blowers

Positive-displacement (PD) blowers, like its name implies, are positive-displacement-type air movers, and are probably the most commonly used type of compressor for dilute-phase pneumatic conveying systems, where the operating pressure typically does not exceed about 18 psig. That pressure is an ideal match with the pressure capability of conventional rotary valves. The PD blower is essentially a constant-speed machine that delivers a relatively constant volume of air over a range of discharge pressures (Figure 6). The solids-to-air ratio for a PD blower dilute phase conveying system is typically from 2:1 to 6:1, up to 10:1 in some cases. PD blowers have also been used for short-distance, dense-phase pneumatic-conveying applications, such as hopper truck unloading. The resistance of the system to which the blower is applied determines the operating pressure.

TABLE 2. FAN PERFORMANCE

Flowrate, ft^3/min	24-in. SP		28-in. SP	
	rpm	BHP	rpm	BHP
15,000	1,770	69.3	1,888	81.2

The twin-lobe Roots-type blower is the oldest and most widely used PD blower. This type consists of a pair of involute profiled (shape of 8) lobes/rotors that rotate inside an oval-shaped casing. One lobe is the driving lobe, which is powered by the external power source, while the driven lobe is driven by a pair of equal-ratio gears. Both the lobes rotate at the same speed, but in opposite directions.

PD blowers have a totally different mechanism than centrifugal fans/blowers and regenerative blowers for compressing air. As the rotors rotate, air is drawn into the inlet side of the cylinder and forced out the outlet side against the system pressure. With each revolution, four such volumes are displaced. The air, which is forced out, is not allowed to come back due to the small internal clearance within the internals of the machine (except for a very small amount called "slip"). There is no change in the volume of the air within the machine, but it merely displaces the air from the suction end to the discharge end, against the discharge-system resistance. In other words, no compression takes place in the machine. However, as the discharge end is reached, compression occurs when the high pressure air in the outlet pipe flows back and meets the trapped air. Due to this shock compression, the thermodynamic efficiency of the machine is relatively low, and it generates relatively high pulsation and high noise.

In order to reduce the pulsation level and noise, three-lobe and four-lobe rotors have been introduced. This allows the lobes to have a slight twist along the rotor axes, which reduces pulsing in the input and output. Since the lobes run within the casing with finite clearances, which are controlled by the gears, no internal lubrication is required. The air is thus delivered free of oil.

Unlike centrifugal fans/blowers, PD blowers deliver, practically, a constant flowrate independent of the discharge pressure conditions. There is a slight flowrate reduction with the increase of system pressure. This is because a very small amount of air "slip" back through the clearance at high discharge pressure. Therefore, in PD blowers, the flowrate is dependent mainly on its operating speed.

The relationship between PD blower power consumption and system pressure drop is shown in Figure 6. Power consumption in PD blowers is proportional to system pressure drop. The lowest power drawn happens when the system pressure is the lowest (in other words, when there is no solids loading in a pneumatic conveying system). Therefore, PD blowers are generally selected for the maximum system pressure, which they may encounter during operation. When in operation, the blower offers considerable power savings, since the power consumed by it depends upon the actual working pressure under which it operates, and not the rated pressure. This is totally different compared to other air movers, such as reciprocating compressors, sliding-vane and screw-type compressors, in which the compression ratio is fixed and the suction air is compressed, according to the compression ratio, regardless of the load conditions. A fixed power is thus consumed by these types of compressors.

PD blower performance curve

The PD blower curve supplied by blower manufacturers typically contains all the information you need to choose the right blower, motor and cooler, if necessary. In a dilute-phase conveying application, after the desired air flowrate and system pressure are determined, it is time to select the PD blower to move bulk solids to the destination reliably. First, find a PD blower that has the right range of air flowrate and pressure from manufacturer catalogs. Then use its blower performance curve to select the right blower speed and associated motor size.

Figure 7 shows the pressure performance curve for the Roots Model 409 RAM blower. For instance, if the required air flow is 600 inlet ft^3/min and system pressure is 8 psi, what are the blower speed and motor size? Start on the upper chart in Figure 7 from the left vertical coordinate and find 600 inlet ft^3/min, move horizontally to the right and find the intersection with the 8-psi pressure curve. Then move straight down to find the right blower speed (rpm) at the horizontal coordinate, 3,000 rpm. This is the speed the blower has to run in order to deliver 600 inlet ft^3/min air flow at 8-psi system pressure resistance.

The input power for a PD blower is largely dependent on the total pressure across the machine. To find the

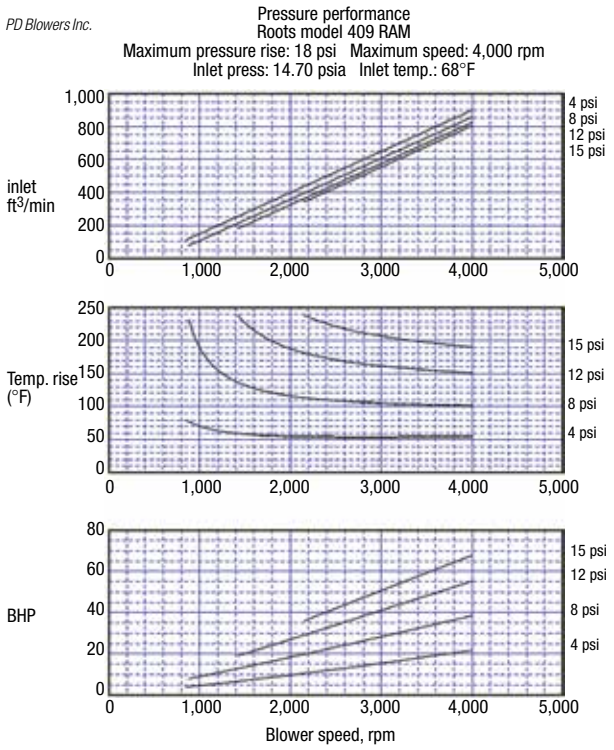

FIGURE 7. The graph shows a blower performance curve for a PD blower

blower power consumption for the blower performance curve, use the lower graph in Figure 7 and move up from 3,000 rpm point. When it intersects the 8-psi curve, move left to find the blower BHP from the left vertical coordinate (28 BHP from Figure 7). To have a decent safety margin and also for possible future capacity release, a 40-hp motor is recommended.

The brake horsepower required to drive the blower can also be estimated quickly by Equation (6):

$$BHP = (P \times Q) / 229 \times \text{eff.}\% \quad \textbf{(6)}$$

where P is the system pressure drop, lb/in.^{2} and Q is the blower inlet-air flowrate, ft^3/min and eff% is the blower efficiency (65–80%). If we use 75% as the blower efficiency here, the calculated BHP is 27.95 hp.

When air is being compressed, a large portion of the energy of compression is dissipated in the form of heat to the gas. The temperature rise of the discharge air in a PD blower is largely dependent on the differential pressure across it. Knowing the value of the temperature rise is critical, since the blower has limits on thermal growth. At high temperature, the lobes can expand into the headplates, causing the unit to seize and possibly causing extensive damage to the unit. In general, the blower average temperature, $(T_{inlet} + T_{out})/2)$ should not exceed 250°F. At temperatures higher than that, a larger blower should be used, or the inlet gas should be cooled.

The temperature rise can be found from the blower curve. Move up from its speed-rpm point, until it reaches the second system-pressure value, then move right to find the temperature rise from the right vertical coordinate, as shown in Figure 8.

Temperature rise (ΔT, in °F), at operating conditions can also be approximated by the following equation:

$$\Delta T = T_{inlet} \times \left[\frac{\left(\frac{P_{outlet}}{P_{inlet}}\right)^{\frac{k-1}{k}}}{\eta} - 1 \right] \quad \textbf{(7)}$$

where η is the entropy efficiency for PD blower, (70~90%); P_{inlet} is the actual absolute inlet pressure in psia, and P_{outlet} is the actual absolute outlet pressure in psia, k is the ratio of the specific heats (for air, 1.4).

The blower performance curves are also based on standard conditions. When the blower operates at non-standard conditions, such as high or low temperature and high altitude, the calculated blower air flow is the actual cubic feet per minute (ACFM), which need to be converted to the blower inlet air flow (ICFM) at standard conditions. Unlike the correction for centrifugal fan to change the pressure, here we keep the pressure unchanged and correct the air flowrate directly. Then, we can specify the correct blower model using the typically increased air flowrate, as well as its speed and motor.

Blower protection

Several ancillary devices are required to protect a PD blower:

Inlet filters. Inlet filters and a filter pressure gage are critical elements in the proper operation of a PD blower. Inlet filters clean the incoming air or gas to minimize the entrance of larger particles into the blower. This filtration is critical to prevent large objects or particles from entering the gas chamber and causing material buildup on the impellers. If the particles are too large, they can cause the unit to seize, which could result in a costly repair. Dirty filters will increase your power consumption and can cause excessive temperature rise on your PD blower. Filters should be cleaned or changed once the pressure drop exceeds 15 in. water column. A filter pressure gage will visually indicate when the filter needs to be changed or cleaned.

Check valves. Check valves are necessary to prevent bulk solids from entering the blower. Make sure to install the valve in the correct direction. A check valve will add about 1 in. water of pressure drop into the system.

Relief valves. Relief valves, either pressure or vacuum, are very important to prevent the damage of the blower unit. Relief valves are available in two types: spring or weighted type. Spring-type valves are typically the most popular and least expensive for a given flow and pressure. Weighted relief valves are available for pressure systems only. They must be mounted in a vertical upright orientation to function properly.

Connectors. Flexible connectors are used to isolate the blower from other system components. This isolation allows for thermal expansion and misalignment of the piping. The two most commonly used connectors are a flexible hose and a single arch-type expansion joint. Flexible hose is typically used for pipe sizes up to 5-in. Schedule-40 pipe. A single arch-type expansion joint is typically used on a flanged connection. Compression-type couplings are also used. These can provide mechanical support, but also allows for thermal expansion. ■

Edited by Scott Jenkins

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CPI PRODUCT REVIEW

CHEMICAL ENGINEERING

Access Intelligence

Paratherm™ GP - a dedicated fluid for the Gas & Oil Industries

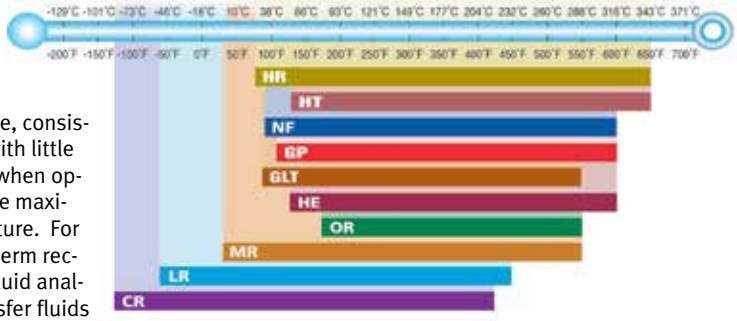
Paratherm GP is a premium-grade heat transfer fluid engineered to outperform standard mineral oils in the chemical and gas processing industries. Paratherm GP offers outstanding performance to 600ºF with low vapor pressure and excellent thermal stability.

The unique chemical structure of Paratherm GP is carefully engineered to resist thermal cracking at elevated temperatures and resists fouling and coking even when pushed to the limits.

- Exceptional thermal stability vs standard mineral oils
- Low volatility
- Film temperature to 650ºF
- Inherently resists fouling of heat exchange surfaces

Applications include:

- Gas Processing
- Chemical Processing



Paratherm GP is designed for reliable, consistent performance with little maintenance even when operated at or near the maximum bulk temperature. For best results, Paratherm recommends routine fluid analysis of all heat transfer fluids at least once per year.

www.paratherm.com

Safest solution for highest vacuum requirements in chemical industry: Magnetically coupled and ATEX certified Roots pumps

OktaLine ATEX by Pfeiffer Vacuum

Pfeiffer Vacuum introduces ATEX certified Roots pumps with a magnetic coupling to the vacuum market. The tried and tested Roots pumps principle was further developed for this certification and named OktaLine ATEX. Vacuum pumps in the OktaLine ATEX series are ideal for processes in explosive areas or for evacuating explosive gases according to the ATEX directive (2014/34/EU): in chemical and process technology applications, industrial applications, coating, the semiconductor industry and research & development. Depending on the application, clients can choose between equipment category 2 and 3. All pumps are suitable for temperature class T3.

The magnetic coupling was a major contribution to the existing tried and tested Roots pumps. These hermetically sealed pumps have very low leakage rates of less than $1x10^{-6}$ Pa m^3/s. Due to the magnetic coupling, it was possible to omit the shaft sealing rings, which are inherent weak points when pressure surges occur and are also high-maintenance. Pumps in the OktaLine ATEX series are resistant to pressure surges of up to 1,600 kPa. In addition, use of the magnetic coupling prevents a gas exchange between process related internal and external atmosphere. OktaLine ATEX is a complete line of pumps that covers the pumping speeds from 280 m^3/h to 5,190 m^3/h. The gear box and bearing areas in the Roots pumps are separated from the gas pumping chamber. Due to the contactless operating principle of the Roots pistons, technically dry operation is ensured. Another advantage is the use of air cooling, as operating costs are significantly lower than with water cooling.

www.pfeiffer-vacuum.com

Coriolis Flow Meters for Additives

Accurate and compact mass flow meters of **Bronkhorst**'s mini CORI-FLOW operate on the fluid independent Coriolis principle and have been developed to measure low flow rates e.g. of additives, from 0,1 g/h to 300 kg/h. The instruments offer a "multi-range" function that allows users to rescale the pre-calibrated measuring range without losing their original accuracy. The flow meters feature fieldbus interface options and additional functions such as totalisation and alarms. They can be tuned according to customer requirements using the RS232/fieldbus interface and free software tools. Bronkhorst flow meters are used in stand-alone applications in laboratories and research centres, as well as integrated systems.

Mini CORI-FLOW flow controllers contain an adaptive PID controller for fast and simple operation of a variety of valve options. Integrated control valves for liquid applications have a degassing adaptor on the top, allowing easy removal of air/gas bubbles.

For liquid dosing, Bronkhorst offers a further possibility of flow control. Instead of a control valve, the flow meter can be combined with a gear pump, eliminating the need to pressurise the fluid at the inlet side. For fast and precise filling or liquid injection applications, Bronkhorst recommends applying their CORI-FILL technology.

www.bronkhorst.com

One size doesn't necessarily fit all.

Check-All Valve offers a wide range of spring settings for proper valve sizing ensuring longer valve life.

Most process valves require an actuator or manual lever to open and close; therefore, the size of pipe determines the size of valve. However, a check valve relies on flow, pressure, temperature, etc. of the media in the application to operate. A fully open and closed check valve avoids the fluttering or rattling associated with premature valve failure. With proper spring selection, a spring assisted check valve can help avoid fluttering or rattling and allows the valve to operate silently eliminating the hammer noise, vibration and pipe collapse associated hydraulic shock also known as water hammer.

Check-All valves are spring-loaded poppet-type check valves engineered for silent operation in any flow orientation. They have a wide range of spring setting or cracking pressure options from 0.125 to 85PSI and virtually anywhere in between (size dependent). Check-All also offers a variety of standard and exotic body and seat materials to meet the most corrosion resistance demands. The sizes range from 1/8" NPT to 20" flange connections and pressure ratings from full vacuum to 10,000PSI. Many options are available within one week. Specialty designs are also available. The Company is ISO 9001:2015 certified and manufactures product lines compliant with CE/PED, CRN, as well NACE testing and other requirements.

www.checkall.com

Multi-agitator system for crucial mixing and dispersion requirements

The Ross VersaMix is a multi-shaft mixer designed for viscous applications requiring a high level of accuracy and batch-to-batch consistency. Three independently driven agitators work in tandem to ensure high-speed fine dispersion, efficient turnover and uniform heating/cooling.

Available in sizes from 1 gallon through 4000 gallons capacity, VersaMix Multi-Shaft Mixers offer reliable scalability from product development to full-scale production. Typically equipped with a three-wing anchor, a high speed disperser and a rotor/stator, the mixer delivers a robust combination of laminar bulk flow and high shear necessary for homogenization and deagglomeration in high viscosity conditions up to several hundred thousand centipoise. Because each agitator is independently driven, the VersaMix imparts a wide range of mixing intensities and flow patterns as the product changes rheologically throughout the batching cycle.

The VersaMix is well-suited for a variety of processing applications including polymer dispersions, filled epoxies, urethanes, advanced composites, greases and lubricants, electronic pastes, battery slurries, cleaning solutions, creams, specialty inks and coatings, hot-melt adhesives, sealants, lotions, gels, toothpaste, flavor emulsions, pharmaceutical suspensions and ointments.

www.mixers.com

Shown is a Ross VersaMix Model VMC-200 with a maximum working capacity of 200 gallons. An air/oil lift raises and lowers the agitators into the vacuum-rated vessel. All product contact surfaces are stainless steel type 316L polished 180-grit finish. The ASME 60-psi jacket on the vessel is insulated with 2" thick mineral wool and sheathed with water-tight stainless steel cladding. The vacuum cover includes multiple charging ports, viewing windows, tank light and a thermoprobe. Finished product is discharged out of a 3" pneumatically-actuated diaphragm valve installed on the tank's conical bottom.

Chemical industry benefits from expansion at Berndorf Band Group

World leading steel belt supplier continues growth with cooler and pastillation systems

The production of goods for the chemical industry has special needs, compared to other branches. Dealing with different materials, corrosion and deformation are a daily issue in the chemical industry. That is why belts from **Berndorf Band Group** are perfect for the production in this sector, providing dynamic strength and resistance against chlorine-induced stress corrosion. Constantly improving their knowledge and product portfolio, the company has closed the gap in its equipment range with cooler and pastillation systems of Esico B.V. and SBS Steel Belt Systems USA. The chemical industry can now profit even more from Berndorf Band Group services.

Innovative and sustainable portfolio extension

As a leading and widely represented provider of steel belts and belt systems, the Austrian company is outstanding in producing and offering various types of steel belts, compatible with the special requirements of the chemical industry, like the right material.

The expansion of the group with the companies Esico B.V. and SBS Steel Belt Systems USA, specialized in the development of pastillation and belt cooler systems as well as the automation of processes for the chemical industry, complement now the range of the Berndorf Band Group. This business area makes the company the only market participant in the USA, Europe and Asia, who has an integrated testcenter for cooling and pastillation systems. By benefitting from this unit, the chemical industry is now able to process sensitive raw material in an easier and safer way.

In future, Berndorf Band Group will position itself as a global full-line supplier of reliable and environmentally friendly as well as high-quality systems with a strong customer focus. By bundling up its strengths around the globe, the Berndorf Band Group creates more efficient corporate structures and advantages for customers. Their convincing quality helps to establish them as one of the leading suppliers worldwide for a wide range of areas and industries.

More about the portfolio of Berndorf Band Group:

www.berndorfband-group.com/

Ultra-High Efficiency Gas Absorption and Particulate Collection in a Space Saving Design

Now Achievable with Proprietary Bionomic Scrubber Technology

Overview

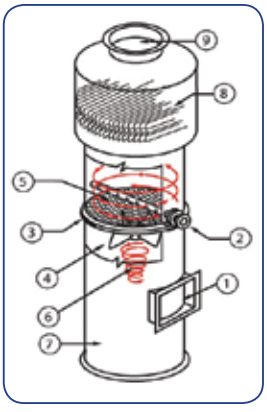
The patented **RotaBed™** Fluidized Bed Scrubber represents a major breakthrough in ultra-high efficiency gas absorption and particulate collection in a space saving non-fouling design. RotaBed is the ideal technology for applications involving particulate laden gas streams or when handling high solids content or scale forming scrubbing liquids.

The key to the scrubber's superior performance is a unique swirl induced Coriolis grid that achieves much greater fluidized bed stability, resulting in more efficient gas mixing and transfer efficiency than less advanced designs. This unique approach to gas-liquid fluidization is accomplished without the need for marbles or plastic spheres that are prone to fouling or replacement due to wear. RotaBed's "packless", highly plug resistant grid cross section is up to 99% open in the fluid contact scrubbing zone and allows the scrubber to deliver exceptionally high gas throughput capacity - over three times greater than comparable size packed towers or tray scrubbers for higher scrubbing efficiency in a smaller diameter vessel.

Designed to handle gas capacities from 500 thru 25,000 cfm, RotaBed is available in mild steel, 304, 316, and AL6XN Stainless Steels, High Nickel Alloys, Titanium FRP, FRP-Dual Laminate, and Polypropylene. Pressure drop range is 1..75" thru 15" w.c. with particulate removal efficiencies of 3 microns and above from 97 to over 99.9%, and water soluble gases up to 99.99%

How It Works

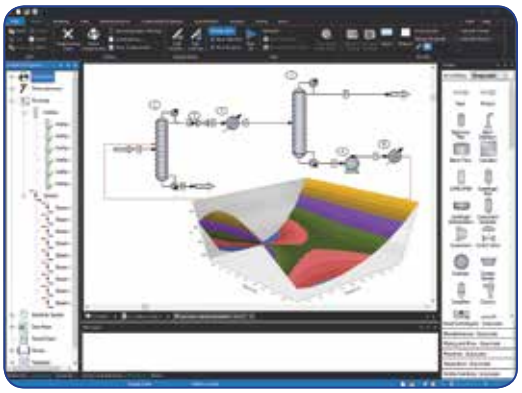
During operation, gas with contaminants enters the RotaBed gas inlet(1) and flows upward. Scrubbing liquid is introduced through fully open non-clog pipe distributors(2) onto the surface of the patented RotaBed Coriolis induced fluidizing grid(3). Single or multiple grid stages are incorporated depending on the number of transfer units required to meet the needed pollutant removal efficiency. The high velocity gas travels in an angular upward path and fluidizes the liquid on the large open area grid surface. Unlike low efficiency static plug flow fluidized beds, the RotaBed shaped grid design utilizes swirl inducing vanes(4) to dramatically increase mass transfer and particulate collection via creation of a rotating Coriolis motion fluidized bed(5). Scrubbing liquid with captured pollutants then vortex drains(6) into the slump(7). The RotaBed cleaned gas passes through a two stage droplet removal stage(8) and exits through the gas outlet(9).



How RotaBed™ Works

www.bionomicind.com

Chemstations readies release of next generation process simulator



Chemstations, Inc. is a step closer to releasing CHEMCAD NXT, which will bring simulation into the world of parallel computing, as beta testing for select customers has begun. Significant speed increases give benefits to users who are running large, complex flowsheets, as the results can be obtained in proportion to the number of cores available on the user's machine. In addition, users with less complex flowsheets can perform thousands, and even tens of thousands, of simulations for sensitivity analyses and optimizations to find correlations and optima that were previously undiscovered in reasonable time frames. Real time, and faster than real time calculation, combined with CHEMCAD NXT's OPC interface, opens more flowsheets to operator training (OTS), plant performance monitoring (PPM), and advanced process control (APC). Currently, other techniques, including reduced models and custom written code, are often the only viable alternatives for the ultra-fast calculation needed for these types of analysis. CHEMCAD NXT now brings comparable speed, which gives the added benefits of rigorous, first principles simulation, ease of model setup, ease of model change/re-use, and widespread understanding of flowsheeting software in the process industries. Users no longer have to rely on external or internal experts to build custom models, and, even in the case where experts are called upon to build the model, all engineering staff is capable of understanding, modifying, and running models built in CHEMCAD NXT.

CHEMCAD NXT builds upon the 30+ years of history at Chemstations in delivering world class simulation software. It has a completely modernized calculation engine developed in highly modular C++ code, and includes proprietary algorithms to maximize overall speed by parallelizing calculations at the most favorable level of a simulation from (1) flash calculations to (2) unit operations to (3) flowsheets to (4) optimizations. This allows users to concentrate on simulation model building rather than understanding parallelization race conditions that can actually make some calculations slower.

CHEMCAD NXT also includes a thoroughly modernized graphical user interface (GUI) using the latest ribbon controls laid out with an in-depth review of user behavior to optimize the simulation experience. A new charting engine has also been incorporated to provide users with presentation ready 2-D, 3-D, and triangle charts.

Please visit http://www.chemstations.com and sign up for Chemstations' newsletter to be alerted when CHEMCAD NXT is available.

www.chemstations.com

CR Clean Air Specialized Scrubbers for Ethylene Oxide (ETO) Control and Abatement

The leaders in Ethylene Oxide mitigation for over 35 years.

Ethylene Oxide (ETO) is a precursor to many chemicals important to the CPI, including ethoxylates, ethanolamines and glycols, which in turn are used in the formulation of various consumer products including detergents, soaps, shampoos and other cleaning agents. It is also used extensively for the sterilization of medical equipment. With a permissible OSHA exposure limit of only 1 ppmv, this carcinogenic, explosive gas must be handled with care; dealing with residual emissions is an ever present challenge. **CR Clean Air**'s innovative ETO scrubber can help ensure your plant does not risk being shut down for non-compliance.

ETO will react with water to form Ethylene Glycol (EG) – but to properly scrub it from a contaminated air stream is not as simple as just deluging it with water. CR Clean Air has developed a comprehensive solution consisting of two main steps – an abortion step to drive the ETO into a liquid solvent, followed by a reaction step in the presence of an acid catalyst to ensure almost full conversion of ETO to EG. Consisting of a packed tower followed by a reactor vessel, the resulting liquid leaving the reactor, having only EG, can be held in a storage reservoir and subsequently recirculated to the packed tower for reuse. A heat exchanger for temperature control ensures the lowest possible temperature liquid returning to the packed tower, thereby maximizing ETO absorption into the scrubbing solution. The CR Clean Air ETO scrubbing system allows for continuous scrubbing with only periodic drainage and replenishment of the scrubbing solution, rather than the need for a constant blowdown.

With over 35 years' experience in the design, engineering and commissioning of these systems, they can provide a comprehensive system consisting of a packed tower, reactor and solution storage tanks, plus the liquid recirculation pumps, heat exchanger, controls and automation required for overall system operation. As an option, they also can provide a separate neutralization system to allow for the liquid effluent to be pH balanced before being discharged to the sewer system.

Systems are commonly of Fiberglas Reinforced Plastic (FRP) construction, however 316 SS is available for high temperature applications where an emergency event may warrant it. All instrumentation can be supplied as Class 1, Div 1 (explosion proof) to ensure safe, reliable operation. When it comes to Ethylene Oxide mitigation, CR Clean Air is the leader. For more information, contact them at (973) 947-8787 or info@crcleanair.com.

www.CRCleanAir.com

Handle virtually any bulk solid material

Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers.

Flexicon's worldwide testing facilities simulate full-size customer equipment and systems, verify performance prior to fabrication, demonstrate newly constructed equipment for visiting customers, and study the performance of new designs.

Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

In 2015 the company doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa. **www.flexicon.com**

Modern Instrumentation Simplifies Maintenance

Modern instrumentation and related maintenance strategies are making it much easier for process plants to perform preventive maintenance.

Self-Diagnosing Instrumentation

Endress+Hauser's smart instruments can send on-board diagnostics, status information and other parameters needed by maintenance people to host systems via digital communications. Once received by a host system, this data is easily accessible from handheld computers, smartphones and control system consoles.

For example, flowmeters from Endress+Hauser are equipped with Heartbeat Technology, which provides a wealth of status and diagnostic information, and performs vital functions such as condition monitoring and in situ-verification.

Condition monitoring recognizes if the performance or the integrity of the flowmeter are impaired. Monitoring values are transmitted to an external condition monitoring host system, such as Endress+Hauser's PC-based FieldCare software. FieldCare can be used to recognize trends in the secondary measured values, and to evaluate relationships among individual parameters.

Legal requirements may call for instruments to be calibrated periodically. Endress+Hauser transmitter electronics continuously run a qualitative assessment so all relevant components which influence the device function and integrity are checked. This confirms that none of the meter components have drifted outside original calibration tolerances. This technology can be used to extend flowmeter calibration frequency, resulting in a tremendous savings.

The Endress+Hauser Field Xpert SMT70 tablet PC can access instrument data, diagnostic information, manuals and parts lists.

Managing Maintenance

Processing all the status and diagnostic data is often a problem. For example, a chemical plant may have more than 4,000 instruments. Having its control system read all the diagnostic information from all 4,000 devices and analyze it for problems would be a daunting problem for the plant's control system programmers.

As an improved alternative, Endress+Hauser offers host software packages that perform all those functions. The packages fall into two basic categories: Instrument management programs, which analyze real-time information from instrumentation; and asset management software, which keeps track of every instrument in the plant and stores vital data, such as manuals and parts lists.

Many plants do not have sufficient information regarding their installed base. Over time plants are modified and instruments change, worsening the situation. One of the best ways to address this issue is by having Endress+Hauser perform an Installed Base Analysis to identify all the instruments, and to recommend best practices for connecting and monitoring each instrument.

www.us.endress.com

Mobile configuration of HART field devices

i.safe MOBILE offers a range of mobile communication devices, such as the smartphone of the series IS520 or the tablet of the series IS910. Both devices have an ANDROID operating system. Depending on the field of application they are available as IECEx Zone1, IECEx Zone2 or none Ex-device.

By linking up the IS520 or the IS910 with the whole system via MobiLInk, the data are available anytime, anywhere.

MobiLink, certified for ATEX Zone1, from Softing provides access to the three most important communication protocols in process automation - HART, FOUNDATION Fieldbus and Profibus PA via a single interface. The link to the i.safe MOBILE devices will be via Bluetooth. The scope of delivery includes drivers to connect field devices via FDT/DTM and FDI technology. The additionally included DevComDroid app by ProComSol, makes it possible to easily and intuitively configure field devices via EDD.

Such complete solutions are supplemented by interfaces which enable mobile access to field devices via the corresponding integration technologies and protocols on site. Field devices are replaced before they break as part of the predictive maintenance strategy. But before maintenance personnel visit the plant, the replacement device is preconfigured on the workbench. The networked smartphone IS520 and the tablet IS910 is also used here in conjunction with the interface in order to enable a fast, simple device replacement with the lowest possible downtime. Parameters are saved in the application based on the description files for the integration technologies, and these are loaded when the device is implemented, which saves time and effort.

An interconnected, compatible solution portfolio of the i.safe MOBILE communication devices, mobile interfaces and professional applications enables technicians on site to monitor and control processes in detail, contributes to more flexibility and helps to increase employee productivity.

www.isafe-mobile.com

IPCO: pastillation in cleanrooms

Solidifying melts and viscous fluids on a steel belt offers several advantages including low-dust generation and extremely uniform granules. With its GMP (Good Manufacturing Practice) -compliant, steel belt-based Rotoform pastillation system, **IPCO** offers a solution with appeal to manufacturers of foodstuffs, cosmetics and pharmaceuticals.

By following the guidelines and regulations that are defined by this code of practice, companies can ensure that their production systems are consistent with international standards and that processes take place with high quality standards. One of the particularly important requirements is to ensure that the production environment is clean and hygienic.

IPCO has recognised these requirements in the hygienic design of its Rotoform pastillation systems for foods, cosmetics and pharmaceutical products. These systems can be used to produce pastilles from products such as fatty acids and fatty alcohols, which can then be processed as tensides in soaps and cleaning agents, or as softening agents, thickening agents and emulsifiers in creams or ointments. Further applications for hygiene-critical products include foodstuffs such as chocolate, cheese, gelatine, sauces, soup concentrates, sorbitol, caramel, chewing gum base material and many more.

High hygiene requirements

The materials and design of the Rotoform units follow the guidelines of the European Hygienic Engineering & Design Group (EHEDG), a group of companies that work together to ensure that hygiene measures are implemented in food production.

For critical products, a risk analysis is drawn up during the concept creation stage. Potential measures range from extracting critical gases and Ex-proof motors for dusty environments to safety shutdown systems. The GMP systems designed by IPCO are therefore well suited to cleanroom processes.

www.ipco.com

Customized sealing and safety solutions for all agitated processes by EKATO

EKATO'S offer:

- Engineered solutions and consulting to sealing requirements for your agitated processes
- Customized sealing solution for best process safety and optimum MTBF containment
- Highly experienced team

Different types of EKATO ESD mechanical seals

EKATO is one of the pioneers in using mechanical seals in agitator technology and has its own mechanical seal production. Since many years EKATO advances the technology continuously, always regarding the requirements of the agitated processes and the safety philosophy of the customers. The EKATO Brand ESD is a synonym for customized sealing solutions in highest quality.

What makes EKATO mechanical seal ESD the best in agitated processes?

- Over 50 years of experience in building mechanical seals and proper auxiliaries for agitators
- Highest number of PTA-Reactor mechanical seals in operation with shaft diameters through 480mm [18.897in]
- Experience with high pressure applications up to 230 bar g design pressure
- Experience with extreme temperature ranges -70°C – 400°C
- Wide range of robust seals and reliable auxiliaries for sealing agitators

EKATO offers consulting in questions concerning sealing technology for:

- new plants
- revamp or upgrade of existing plants
- engineering studies

EKATO - Your best partner for best matched agitation and sealing systems, out of one hand!

www.ekato.com

Sizable Innovations In Productivity… One Particle At A Time.

Midwestern Industries, Inc. (Massillon, OH), a leading manufacturing mainstay of innovation for the screening industry since 1953, has recently launched their operator-friendly Electro-Lift separator screen changing system. The revolutionary, ergonomically designed lift system is electrically powered to assist in making separator screen changes easier, faster, and safer. Engineered with a 120 volt sealed gear-driven system, operation is as simple as plugging into any convenient outlet and pressing a switch.

Rounding-out productivity: Additionally, they have expanded their range of screens and parts for round vibratory separators–typically ideal for very fine material applications such as such as pharmaceuticals, powders, food (flour, corn meal, salt, chocolate, etc.), plastics, liquid solids, and ceramics that require precise separation that can be achieved on round vibratory separator machines.

This round screen lineup includes: Perforated screens, Bulls-eye screens, Sandwich screens, Wagon wheel screens, Ultrasonic screens, and custom woven screens.

Newly developed within the past year, Midwestern has also incorporated a new process for full epoxy mounting. This new process allows the epoxy to cure quickly which enables Midwestern to ship screens the same day. The advanced epoxy allows users to switch from different mounts for longer life. Each screen is individually boxed with an FDA approved gasket installed– at no extra charge.

In-house custom replacement screening capabilities have also been expanded to include: Slotted screens, Perforated plates, Interkleen® Screens, and Clear opening screens. Accessories include: Crowned bar rubber, Formed edges and hooks, and side rail.

Unparalleled Testing Expanded: Midwestern has also recently expanded their advanced, full-scale screening test facility capabilities for customers–FREE of charge. Comprised of over 10,000 Sq. Ft. of Midwestern's manufacturing headquarters (147,000 Sq. Ft.), the Midwestern Materials Testing Lab is an invaluable testing facility platform–considered one of the best tools for customers to make informed decisions about their screening processes. Ultimately, end-users can use the facility to gain vital quantitative data into their screening processes via running 'real-time', full-scale material tests for new applications, as well as improving on existing ones.

Known throughout the industry as "The Sizing People®", Midwestern's comprehensive product line has the ability to screen and separate particles from 20 microns and up. We achieve these demanding standards by leveraging advanced precision manufacturing techniques–in addition to screening accessories that drive optimal productivity.

Speak to a sales representative today to discuss your specific round screening needs by calling: **877-4-SIZING** (877-474-9464) or visit:

www.midwesternind.com

Optimizing critical fired heaters is now easier than ever

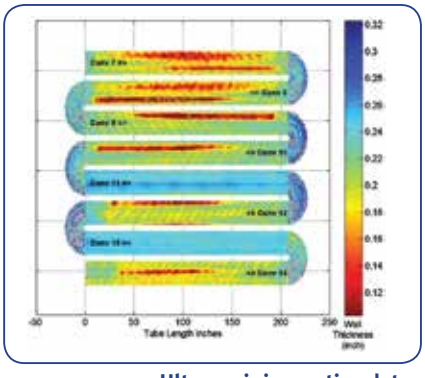
Quest Integrity provides industry expertise and engineering optimization planning and management to increase the life cycle value of fired heater assets

Unexpected asset failures present a number of complications to a facility, including costly repair and production interruptions. Historically, asset reliability and management methodologies have been reactive – only adjusting practices once a costly failure has already occurred. However, today's modern technologies allow operators to proactively manage their assets, mitigating many of the risks associated with premature asset failure. Significant improvements in technology innovation and reliability practices provide operators with life extension opportunities that were not available just a decade ago.

Quest Integrity understands that unique assets require unique solutions. Due to specific operator and individual asset requirements, a general model for asset integrity optimization is not an effective long-term solution. A powerful optimization management strategy should be specifically designed to address the current and future condition of the asset, achieving a higher level of performance and reliability, while decreasing the risk of unplanned shutdowns. Customized for the life-cycle of each individual fired heater asset, Quest Integrity's Fired Heater Optimization program consists of a multi-disciplinary inspection and engineering approach that includes tube creep and corrosion damage measurement and assessment, infrared thermometry (IR) data management, ultrasonic in-line inspection and remote digital visual inspection (RDVI). A variety of engineering assessments, including fitness-for-service, remaining life, risk assessment and failure analysis are utilized to significantly extend asset life, effectively managing cost and preventing catastrophic failures.

Depending on the condition of an asset, Quest Integrity's team of dedicated technical experts assist operators in determining the appropriate strategic action plan to ensure optimal performance and reliability of fired heaters.

Quest Integrity is a global leader in the development and delivery of asset integrity and reliability management services and solutions. The company's solutions consist of technology-enabled, advanced inspection and engineering assessment services and products that help organizations improve operational planning, increase profitability, and reduce operational and safety risks.



Ultrasonic inspection data indicating areas of severe wall thinning in fired heater tubing

www.questintegrity.com

Alleviate headaches caused by faulty steam traps

The TrapMan system from TLV uses a combination of ultrasonic and temperature measurement, backed up by a powerful database, to diagnose steam trap condition

Leaking and blowing steam traps with resulting energy loss and back pressure can hurt operating performance. Condensate backing up in a steam system from a blocked trap can potentially cause damage to critical equipment or reduce process performance. Opened bypass valves, to drain the steam system to grade, create a waste of energy and potential safety issues. All of these headaches can be relieved through a steam trap management program based on **TLV**'s TrapMan system for testing and reporting.

TrapMan is the first diagnostic instrument combining both ultrasonic and temperature readings for accuracy to make an automatic judgment of a steam trap's operating condition. TrapMan records both readings of the operating steam trap, compares it to a specific signature developed for that actual trap model, and diagnoses its condition based on empirical data. The TrapMan system has over 4,200 unique signatures for different makes and models of steam traps, providing superior capability to make an accurate, automatic judgment of specific steam trap model performance.

The TrapMan system includes powerful TrapManager database software. TrapManager provides the capability to retain historical test and installation records, allowing for detailed analysis and reporting. The software can also be configured to a user's needs to predetermine inspection routes, capture plant data that is unique to the site, then track and plan preventative maintenance. TrapManager software is compatible with Windows XP/Vista/7 and is functional (not yet fully supported) with Windows 8.

The TrapMan is easy to learn, weighs only 2 lbs and is intrinsically safe. TrapMan hardware eliminates variations in testing caused by human error, and its accuracy is validated by Lloyd's Register. Potential users can learn more about TrapMan's ability to enhance productivity, reliability, safety, and energy efficiency benefits.

www.tlv.com

Properly-working steam traps save time and money, and increase safety

Comprehensive solutions for process industries

Sulzer shows how its state-of-the-art products and services can boost process operations at Chem Show 2019

Increased productivity and efficiency to improve process operations is a major goal for businesses in the chemical industry. Sulzer Chemtech will be showing key tools to help them address these issues at Chem Show 2019. The company will showcase its latest mass transfer products and solutions that bring plant operations to the next level. By choosing these technologies and services, processing companies can optimize performance, efficiency, reliability and productivity with a fast return on investment (ROI).

The goal of Chem Show is to bring together professionals and ideas to improve chemical processing equipment and application practices, including mixing and separation processes. These are key in the fast and efficient delivery of high-quality chemicals. Thanks to its in-depth understanding and extensive expertise, Sulzer Chemtech, the leader in separation and mixing technology, can address the needs of businesses in the chemical processing industry and increase their competitiveness.

Visitors to the stand will be able to speak to experts from Sulzer about mass transfer equipment and process plant solutions for the chemical industry.

As a full-service-provider for mass transfer equipment and process plant solutions, the company can deliver reliable and innovative mass transfer components, entire plants as well as a wide range of dedicated engineering services.

Key products on display at Chem Show 2019 will be Sulzer's vast portfolio of column internals, such as NeXRing™ – the latest generation of random packings. These feature an innovative design that, when used to replace conventional second-generation rings, can increase column capacity by 25% to 35% while maintaining or even increasing the overall column efficiency.

Also on stand will be MellaCarbon™ range of carbon fiber reinforced internals, which will be of particular interest to manufacturers of specialty chemicals. These lightweight components are particularly durable, as they are extremely resistant to corrosion, high temperatures and thermal shocks.

Sulzer Chemtech's Process Plant unit will also showcase its leading role as a provider of complete modular plants. The company can support process plant projects with local points of contact in the U.S.A.,

Visitors will be able to learn about Sulzer Chemtech's latest developments and process plant capabilities through virtual reality (VR) and augmented reality (AR) apps. These virtual environments will provide a unique, engaging, hands-on experience of real-world chemical process plants and how Sulzer's equipment fits into them.

Visit Sulzer Chemtech on stand 555 at Chem Show 2019. October 22-24, 2019 – Javits Center, New York City, U.S.

www.sulzer.com

Solvent Drying

The model TURBO-DRYER being exhibited at the 2019 Chem Show duplicates the actions of a full scale production dryer.

The material being dried is stationary on the rotating trays for a full revolution on each shelf. The material only moves when it is transferred through the slots to the shelf below.

Material is handled very gently with a minimum of particle breakage and fines formation. Therefore dust carryover Is very low, generally less than 1% of the throughput.

The dryer handles both water and solvent wet materials and removes solvents down to ppm levels without the need for vacuum.

Recent installations include drying: Lithium Carbonate, solvent wet Brominated fire retardant, animal feed supplement, carbon fiber and silver powder.

www.wyssmont.com

B&P Littleford's Innovative Compounding Technology

For more than a century, **B&P Littleford**'s industrial equipment has been helping customers make their manufacturing processes better, more efficient, and more profitable. B&P designs and builds a wide spectrum of mixing, drying, extruding, compounding, and centrifugal separation equipment for large- or small-scale manufacturing applications.

Their exclusive TriVolution Compounder (3 strokes per screw revolution) offers a dramatic shift in process performance while using less energy than competitive products. The design basis enables an easy transition for new owners as the unit retains the basic modularity of most familiar compounding extruders. This machine – like all of the B&P Littleford compounding equipment – is designed and built in Saginaw, MI. Full-service testing, parts, and rental equipment are readily available for the full line of products, as well.

Whether it is planning a new product, seeking to enhance production of a current product line, modifying a formula, trying to boost environmental performance, or simply need increased efficiency in production, B&P Littleford will customize an industrial machine solution to fit their customers' needs.

See the TriVolution Compounder in action at K Fair by visiting B&P Littleford at Booth 8BD27!

www.bplittleford.com

Fluid sealing can be extremely difficult in harsh conditions.

Abrasion, strong chemicals, high temperatures and irregular surfaces can all contribute to leaks and short seal lifespans.

A few of the many DeWAL PTFE and UHMW films and tapes used for gaskets, expansion joints, valves and diaphragms.

To prevent seal failure in these conditions, **DeWAL** has developed more than a dozen durable, bondable PTFE and UHMW film and tape compositions for gaskets, expansion joints, valve seals and diaphragms.
Some examples:

DW601. DW601 is a fiber-filled PTFE tape in a number of thicknesses. It combines flexibility with very good deformation in load-carrying situations and is used for running against hard mating surfaces like cold-rolled steel.

DW602. With a low coefficient of friction and reliable product stability at very high temperatures, DW602 is a specially filled PTFE compound coated with a silicone adhesive. It is specified for many seal applications. Strong, lube-free, dynamic and durable, it is resistant to deformation under load.

DW611. A filled PTFE compound with special grades of carbon graphite, this black tape exhibits low friction and excellent wear properties in watery applications.

Dynaglide 633. For seals, gaskets or sliding bearings, this is one of many Dynaglide PTFE tapes with excellent friction and abrasion properties and is used on many different soft mating substrates. It is often used to prevent wear on painted surfaces

DW203. DW203 is an unsintered PTFE film used primarily for electrical insulation. It is fibrilated for high strength in the machine direction and is chemically inert, even in extreme temperatures. With notable drape characteristics, it is used for gaskets, expansion joints, valve seals and diaphragms.

DW134. DW134 is a series of PTFE impregnated glass fabric tapes. The PTFE provides a smooth anti-stick surface while the glass fabric provides extra strength and dimensional stability. In a range of widths and thicknesses, DW134s are all coated with a high temperature silicone adhesive.

DW232p. DW232p is ideal for venting gases when holding liquids, for separating oil and water, for gasketing and for filtering where high temperatures and caustic chemicals are present. It is a dimensionally stable, crush resistant, low density porous skived PTFE.
DW 402p & 402hp. Micro-porous, **DW 402p** is specified for gas and liquid filtration, medical test kits, wicks, and low dielectric constant wrap. Even stronger and more porous, **DW402hp** is excellent for liquid and air filtration, vents, diagnostics, wicks and support media for finer membrane structures. Both UHMW films are chemically inert and can be hydrophilic or hydrophobic.

DeWAL, part of Rogers Corp., has designed and manufactured PTFE and UHMW films and tapes in its RI facility since 1974.

www.dewal.com

Jenike & Johanson Engineering Services

Jenike & Johanson, Inc. is the world's leading technology company for bulk material handling, processing, and storage. They deliver engineered solutions to achieve reliable powder and bulk solids flow based on proven theories and decades of project experience. With their skilled, highly technical team of experts and industry-leading innovations, they have successfully delivered bulk material engineering solutions for more than 55 years.

Bulk materials and their flow properties are at the core of all Jenike & Johanson's work. Every project (7,500+ to date) is truly unique. Clients are offered maximum flexibility in selecting services required to meet their bulk material handling needs. Jenike & Johanson does not follow the "one size fits all" concept – which can be a dangerous pitfall in engineering. Decisions made during the feasibility and engineering stages of a project are critically important for its success. If bulk solids systems are not engineered from the outset to handle the unique characteristics of the materials, process start-up time can be significantly delayed and design capacity may never be reached.

The engineers at Jenike & Johanson are renowned experts in the field of bulk material engineering. They are frequent keynote speakers at major industry events, routinely deliver informative webinars and customized courses, and publish thoughtful technical articles in top industry journals and publications – all this in order to provide clients with the latest insight on cutting-edge methodologies which make the powder and bulk solids handling aspect of the business run seamlessly.

The chemicals industry provides the building blocks for companies manufacturing paints, pigments, coatings, adhesives, resins, consumer products, and foods. 75% of all chemicals are handled in bulk solid form during manufacturing. When feeding powders to reactors or conveying wet cake from a centrifuge to a dryer, poor material flow can result in throughput limitations, non-uniform product, or dust emissions/spillage.

www.jenike.com

Drive Performance Improvement with Existing Data

Chemical manufacturing organizations face more challenges than ever before, but one truth is constant: if an organization's assets are healthy, the plant is performing and producing. But keeping assets healthy and improving production for optimum performance means going beyond the traditional methods of manual rounds, analyzing siloed data from multiple applications, and relying on outmoded communications tools for collaboration.

To help organizations take steps to manage their data and optimize their assets and resources for sustained high-performing production, **Emerson** has developed Plantweb™ Optics—an asset performance platform for managing asset health across the enterprise. Plantweb Optics combines the data from multiple applications into asset-centric information to deliver persona-based alerts and KPIs for production assets.

Chemical processing teams can keep track of reliability and monitor all assets in one place, from wherever they may be.

- **Connect assets with experts** – Most organizations can't maintain a dedicated subject matter expert (SME) to analyze asset data at every site. One large U.S. chemical manufacturer solved this problem with Plantweb Optics. Plantweb Optics will monitor assets online and data will be automatically parsed, organized, and delivered to the mobile device of a traveling SME. Rather than having an individual spend hours collecting data and creating reports, Plantweb Optics transmits a health score that the SME can quickly and easily interpret, allowing him to immediately begin collaborating with the on-site technicians to resolve any issues.

- **Get relevant information at the right time** – When assets fail unexpectedly, they typically generate unexpected costs. For a U.S. life sciences company, this was illustrated every time its clean-room exhaust fans failed, forcing them to stop production and decontaminate the clean room. By installing Plantweb Optics and Emerson's AMS 9420 wireless vibration transmitters, the team went from no visibility of fan health to full visibility almost overnight. Now, intuitive health scores for the fans let the team plan maintenance rather than running the assets to failure.

As chemical manufacturers move from the manual model of yesterday—SME's laboriously analyzing data at every plant—to the digital plants and processes of the future, they're finding more efficient ways to connect critical data in disparate systems with an increasingly mobile and flexible staff. Plantweb Optics helps these manufacturers close the gap between data and analytics at all levels of the organization, making it easier to maintain healthy, high-performing production across their enterprise.

www. Emerson.com/PlantwebOptics

Gas Composition Matters for Flow Meter Accuracy

Case study shows flow meters calibrated to measure "natural gas" were programmed on incorrect gas compositions leading to accuracy errors of ±10%.

Natural gas is colorless and odorless, so natural gas processors and transporters add odorant to the gas to identify leaks by smell. Odorization systems typically require independent measurements of the amount of natural gas odorized and the amount of odorant consumed. Maintaining the proper ratio of odorant to gas is essential for quality control.

The North American Energy Standards Board (NAESB) suggests composition ranges of various components in natural gas, with a typical analysis contains approximately 94.9 percent methane, 2.5 percent ethane, 1.6 percent nitrogen, and 1.0 percent other components. However, it is reported that over 10 percent ethane can be present in natural gas obtained from horizontal drilling. In contrast, significant amounts of heavier hydrocarbons may be present in natural gas from other sources. These types of differences in composition can adversely affect flow meter performance leading to accuracy errors of ±10%.

In a recent case study of a transporter in Europe, the existing flow meters were configured for the NAESB's typical composition and calibrated using the factory-standard surrogate natural gas. The composition of the actual natural gas was significantly different, it varied by site, and was likely to change over time.

The transporter wanted the ability to configure the actual composition of its natural gas in the field without returning the flow meters to the factory for calibration, all without loss of accuracy.

The manufacturer used the actual natural gas compositions to perform calculations that confirmed the flow measurement errors were like those experienced by the transporter. The traditional approach to resolve this problem would be to return the flow meters to the factory for recalibration with various surrogate gases representative of the various natural gas streams. This was not acceptable to the transporter in the short term and would have made compensating for future composition cumbersome in the long term.

Consequently, the existing flow meters were equipped with a gas selection library programmed into the flow meters' electronics. Using this technology, each component in the natural gas could be configured in 0.1-percent increments in the field to measure the flowing natural gas with no loss of accuracy.

As a result, the transporter was able to create a schedule to test for changes in gas composition. When changes were detected, the flow meters' gas selection technology was used to program the new gas composition into the electronics to maintain the highest gas flow measurement accuracy.

www.foxthermal.com

Gas	NAESB Range	Texas	Nigeria	Canada	Italy
Methane	87.0 - 96.0	93.1	86.5	85.8	85.6
Ethane	1.8 - 5.1	3.0	7.2	4.8	7.7
Nitrogen	1.3 - 5.6	0.1	0.1	4.6	3.1
Carbon Dioxide	0.1 - 1.0	2.1	0.7	2.2	1.3
Propane	0.1 - 1.5	0.8	3.5	2.3	1.7
Iso-Butane	0.01 - 0.3	0.2	0.8	0.1	0.2
Normal-Butane	0.01 - 0.3	0.24	0.67	0.15	0.30
Oxygen	0.01 - 0.1	0.00	0.00	0.00	0.00
Iso-Pentane	Trace - 0.14	0.12	0.23	0.01	0.12
Normal-Pentane	Trace - 0.14	0.08	0.15	0.01	0.06
Hexanes Plus	Trace - 0.06	0.24	0.11	0.01	0.05
H2	Trace - 0.02	0.00	0.00	0.00	0.00
% Error	**N/A**	**+4.0**	**+7.9**	**+9.8**	**+10.1**

Chemical Compositions of Natural Gas (in mole percent)

New Chemistry for Mild Steel Corrosion Control from Nalco Water

Nalco Water, an Ecolab company, announces a new non-phosphorous program providing excellent mild-steel corrosion control and calcium carbonate scale control that allows cooling water systems to reach higher cycles of concentration and higher pHs without compromising performance. With the ability to withstand high cycles and long holding time index application, this program offers constant protection in a range of applications. Additionally, it offers superior performance in varying water conditions with minimal dosage adjustments. Flexible and robust, it allows systems to reach higher pH conditions to help strip ammonia from the water. By eliminating added phosphate and allowing for better ammonia stripping, this unique, non-phosphorous program removes two major aquatic nutrients for bacteria. Furthermore, this program offers wider application windows for performance in high-conductivity water with high levels of chlorides. It is tolerant to fluctuation in the makeup water and tower, requiring minimal treatment program adjustments.

www.ecolab.com/nalco-water

Flowrox Reinforces Its Filtration Portfolio

Flowrox, formerly known as Larox Flowsys, has more than 40 years of experience in solid/liquid separation, flow control, elastomer technology and technical textiles. After acquiring American Spare Parts Depot and NovaTek, Swedish filtration technology company, Flowrox strengthened its filtration portfolio.

Flowrox Filtration Solutions

The team of experienced Flowrox professionals provides you with the whole package of services starting with a detailed analysis of the process, filtration testing, equipment selection and sizing according to the test results and practical experience. Flowrox offers full support at delivery, installation, start-up, operation and maintenance. Modernizations, refurbishments, spare parts and maintenance support are also available.

Flowrox Filter Press (FP) was engineered together with plant operators and is well appreciated especially among leading global metal production companies. Flowrox FP presents fully automatic operation, high quality, superb performance and high availability. Common applications for Flowrox Filter Press are zinc refinery processes, silver, gypsum and chlorine removal, polishing, wastewater streams, flue-gas desulfurization and energy metals.

Flowrox Ceramic Disc (CD) Filter is highly efficient and has the lowest energy consumption. Besides that, it requires low investment and delivers clear filtrate with a dry cake. Compared to conventional vacuum filters, it consumes approximately 90 % less energy. Flowrox CD filter operates continuously with high capacity and is a cost-efficient solution for many concentrator and tailings processes. Applications for Flowrox CD filter are divided into concentrates and tailings. The concentrate applications most suitable for the Flowrox CD filter are iron, copper, zinc, gold and phosphates. Typical tailings applications are iron, copper, molybdenum, phosphorus and quartz sand.

Improve Process Performance with Smart Solutions™

Flowrox Smart Solutions are a new way to combine processes and Industrial Internet of Things (IIoT). Specifically for filtration, Flowrox has developed a Flowrox Smart Filtration Digital Service, a turnkey solution that can be installed on any filter. It enables remote, real-time insight into the filtration process and helps to troubleshoot and significantly optimize production. Smart Filtration utilizes existing control system and sensors and connects the filters to the Flowrox Malibu online portal. DCS (Distributed Control System) integration is not necessary, but it can be arranged upon request. Malibu also automatically generates user-defined reports which are easy to read. Data analysis provided by Smart Filtration can be used for comparing filter's productivity, quality changes, energy consumption, and production output, to determine the reasons for its waiting time, alarms and more.

www.flowrox.com

Flowrox Filter Press (FP) presents fully automatic operation, high quality, superb performance and high availability.

Airflow Measurement for Challenging Applications

The Chemical and Petrochemical processes of today need precise, reliable, and trusted solutions to airflow measurement problems on-site.

One of the biggest problems facing operators today is the push for better functionality, cost-savings, and the need for greater efficiency. When equipment fails, the process shuts down. This not only costs the plant money, but it can lead to dangerous consequences, especially when processing flammable or combustible materials. It's imperative that instrumentation give back accurate readings of what is happening in the process to avoid catastrophic failures.

The chemical and petrochemical plants of today are in a state of transition. Plant managers are tasked with making more out of less while increasing quality simultaneously. The petrochemical industry requires instrumentation that can be used in high temperatures and in corrosive environments. For instance, an air flow meter used to measure airflow to air dryers must be able to withstand harsh conditions while performing accurately over time.

Better functionality of instrumentation results in greater control over processes and improved efficiencies. When the operator can trust that the airflow measurement system is not going to produce false readings due to particulate matter clogging the sensor elements, maintenance costs go down and production time stays consistent. Some manufacturers offer automatic purge systems to ensure that the sensing elements are free of debris and can measure accurately without regular inspection or cleaning.

Trying to save money without sacrificing quality is a tough task, but thorough research on the specifications and features of flow measurement devices will result in finding the best solution. Can the flow meter perform well under harsh conditions? Can the manufacturer provide a system that will operate in tight installations without long straight runs? Will there be sensor drift over time? How often will the flow meter need recalibration?

The search for instrumentation and equipment to make the process run more efficiently is complicated and can take months, sometimes years. Specifying engineers must ensure that the manufacturer can fulfill the unique requirements of the processes found onsite without major modifications to existing pipes or ducts that would lead to extended project times and added costs.

www.airmonitor.com

How Do I account for ASME B16.47 Series B Drilling When Specifying a Rubber Expansion Joint?

Conventional control rod set up can be challenging when the flanges you want to attach have ASME b16.47 Series B drilling. Generally, the attachment area for a traditional triangular control rod plate is greatly reduced. With ASME Series B16.47 Series B Drilling the bolt circle for the flange is closer to the O.D. of the pipe than Series A drilling.

The best rubber expansion joint design to consider is an "Interior Tie Rod" design. Using this design will eliminate the complication of a traditional control rod set up on the back side of the mating flange where the rod plates do not have enough webbing from the I.D. of the plate to the I.D. of the holes on an ASME B16.47 Series B flange.

The only other option a client might have when dealing with ASME B16.47 is a control rod set up where thick fabricated split flange plates are supplied so that the resultant thrust loads from the rubber expansion joints are evenly distributed to every bolt hold.

www.procoproducts.com

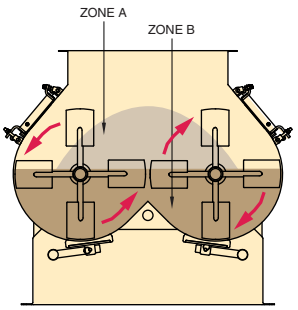
Fast, homogenous mixing

The Bella XN fluidized zone mixer from Dynamic Air is a twin-shaft design that uses a "weightless" central fluidized area to provide thorough yet gentle mixing of dry products

The twin-shaft Bella mixer

The Bella fluidized-zone twin-shaft paddle mixer by **Dynamic Air** achieves fast, high-capacity, low-shear, precision mixing of either dry bulk solids or liquids with solids. Regardless of particle size, shape or density, materials are mixed with a fast, efficient, and gentle action, with typical mixing times of 15–30 s. A weightless zone created by low-speed counter-rotating paddles generates low friction without shear. This makes it ideal for abrasive products and fragile products that cannot tolerate rough handling. Even flakes or spray-dried bodies remain intact.

The Bella mixer consists of twin drums which have two counter-rotating agitators with specifically angled paddles. The paddles sweep the entire bottom of both mixer drums and yet allow the mixer to be started under full load (Figure 1). The material in the mixer moves in a horizontal counter-clockwise direction at the perimeter while simultaneously moving both left and right in the center (Figure 2). The material in Zone B (Figure 1) is in its normal gravimetric state as it is being moved and dispersed. In Zone A, a weightless zone is created which effectively lifts the ingredients to an almost weightless state, allowing them to move freely and randomly, regardless of particle size and density. Thus the two zones' interaction becomes highly efficient as every particle moves rapidly to create a highly homogeneous mix, the key to the Bella mixer mixing technology for fast, precise mixing.



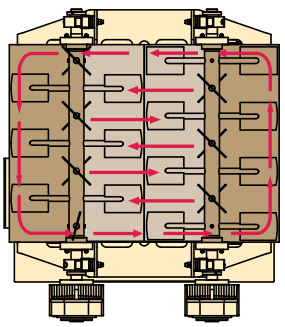


Figure 1 (right, top): In Zone A, fluidization promotes thorough mixing. Figure 2 (right): Material interchange between the two drums

The Bella mixer is available in stainless steel and mild steel construction.

www.dynamicair.com/products/mixers.html

Your First and Only Call for Refractory


KORUNDAL XD

There are many different vessels in a refinery that require refractory linings and each one can use several different kinds of refractory inside. The process of identifying and obtaining refractory can be complicated, especially when multiple sources are used. **HarbisonWalker International** (HWI) aims to resolve this complication by not only offering every product needed in a refinery, but by also identifying which products and how much are needed. They can provide products for fluid catalytic cracking units (FCCU), sulfur recovery units (SRU), and fired heaters and reformers. Technical support is available to identify the brands required for a given unit and even offer some advice for improvements. Bills of material and refractory drawings can be made for anything from a simple duct to the most complex brick linings.

For the FCCU, HWI can offer excellent products that are made to endure the challenging environment inside. For reactor and regenerator walls, GREENLITE®-45-L has been used for many years with great success. This product's success is largely due to the superior strength-to-density ratio created from the use of Greenlite® Aggregate, a proprietary synthetic lightweight aggregate with great strength. There is even a version available that can be pumped or shotcreted into place. For more abrasive areas of the FCCU like the riser and transfer lines, the medium-weight products HPV® 110 and LO-ABRADE® HPI have an excellent abrasion resistance as low as 12cc loss maximum (tested with ASTM C704), but still provide good heat insulation. For areas with the worst abrasion problems, GREENKLEEN® 60 (for casting) and EXCELERATE ABR (for ramming) are perfect with abrasion loss as low as 5cc loss max.

In SRU thermal reactors only the highest quality refractory brick can be used for the hot face layer of the refractory lining. Brick in this area need to have the best creep resistance to hold up to the extremely high temperatures for many years. This is why KORUNDAL XD® has been the go-to refractory brick for SRU thermal reactors for decades that few competitors can match. Behind the hot face layer will be a layer of GREENTHERM™ insulating firebrick or KAST-O-LITE® lightweight castable. Other areas downstream of the thermal reactor will require a variety of lightweight and dense monolithic refractory, all of which HWI can provide solutions for.

Fired heaters can range widely by design and function. No matter what the design or temperature, HWI can provide the refractory needed. With a range of insulating castables, all temperature ranges can be covered. HWI even manufactures its own ceramic fiber blanket which can be used as-is for blanket linings, or purchased and installed as a folded module for better insulation and durability in service. Creep resistant firebrick are also available for tunnel and division walls where deformation of refractory over time causes these walls to break down.

No matter who provided the refractory in the past, or if the last time it was repaired was in the '60s, HWI can provide the proper refractory product needed. Experts are available to help design the lining needed for any unit. We strive to be your first and only call for refractory products.

www.thinkhwi.com

Milton Roy Critical Chemical Dosing Pumps and Mixing Systems

Built on a strong reputation of reliability, **Milton Roy** combines vast industry experience, a proven track record, and a culture of continuous technological improvement to deliver the most comprehensive portfolio of metering pumps, mixers and control systems for chemical metering applications used in upstream applications and industrial water and wastewater treatment.

Milton Roy's PRIMEROYAL® Series metering pumps are the industry's most powerful metering pumps, capable of delivering 20,000 psig to overcome the extreme pressures associated with ultra-deep offshore applications. The API 675 compliant PRIMEROYAL pump is designed for consistent and accurate delivery of flow assurance chemicals to enhance offshore product recovery, eliminate corrosion, and prevent hydrates or wax deposit formations. The PRIMEROYAL range provides accurate dosing of a broad spectrum of fluids at flow rates that can reach maximum 13,068 gph (49,470 l/h) in the triplex configuration. With its modular design, multiple liquid ends, and wide range of options, PRIMEROYAL pumps can be configured precisely for many dosing applications.

The workhorse of the Milton Roy portfolio is the mROY® metering pump. This pump has been upgraded and offers enhanced safety, improved hydraulic efficiency, easier startup and maintenance, and the same accuracy and reliable performance for which Milton Roy is known. Produced in a variety of models and frame sizes that provide capacities from 0.20 gallons per hour up to 87 gallons per hour in a simplex configuration, the mROY metering pump boasts a hydraulically balanced diaphragm with 96,000-hour design life and a three-year warranty.

Milton Roy's PROTEUS® is the most intelligent chemical metering pump for the water and wastewater, chemical, power generation, oil and gas, agricultural, pulp and paper, and textile industries. PROTEUS is built on a universal

technology platform with the ability to adapt as technology evolves. It features a mechanically actuated diaphragm driven by advanced variable speed technology for accurate and reliable performance. PROTEUS is available in manual or enhanced models with flow rates 0.006 to 18 gallons per hour (0.023 to 68 liters per hour to provide complete process control.

In addition to metering pumps, Milton Roy offers a range of mixers and agitators used for water treatment processes and flocculation and coagulation applications. Milton Roy provides side entry mixers used by crude oil storage operators to blend crude of different gravities together until it can be sent to refineries. This efficient blending keeps basic sediment and water (BS&W) from settling at the tank bottom, which protects storage tanks, and maximizes storage space for operators.

www.miltonroy.com

Economic Indicators

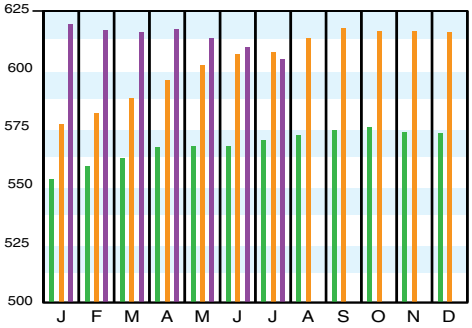
2017 2018 2019

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	July '19 Prelim.	June '19 Final	July '18 Final
CE Index	604.6	609.5	607.2
Equipment	735.8	743.2	740.1
Heat exchangers & tanks	646.8	659.7	656.2
Process machinery	722.2	727.0	724.3
Pipe, valves & fittings	953.9	955.7	966.5
Process instruments	415.4	416.4	422.6
Pumps & compressors	1068.2	1068.5	1025.8
Electrical equipment	558.3	557.7	538.0
Structural supports & misc.	796.4	810.9	809.9
Construction labor	335.6	335.4	335.7
Buildings	593.9	595.8	602.5
Engineering & supervision	314.3	313.8	307.6

Annual Index:
2011 = 585.7
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1

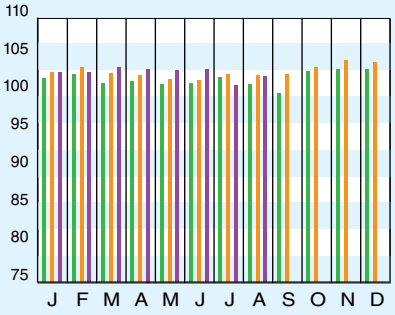


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

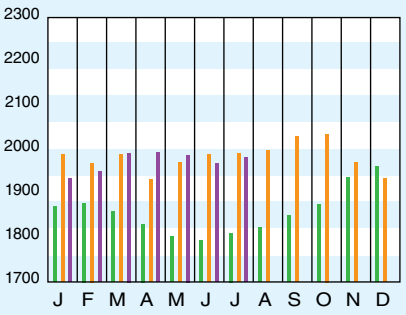
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS		YEAR AGO	
CPI output index (2012 = 100)	Aug.'19 = 102.2		Jul.'19 = 101.1	Jun.'19 = 101.5	Aug.'18 = 103.7	
CPI value of output, $ billions	Jul.'19 = 1,981.9		Jun.'19 = 1,966.1	May '19 = 1,984.8	Jul.'18 = 1,992.7	
CPI operating rate, %	Aug.'19 = 76.1		Jul.'19 = 75.4	Jun.'19 = 75.7	Aug.'18 = 78.1	
Producer prices, industrial chemicals (1982 = 100)	Aug.'19 = 248.3		Jul.'19 = 256.3	Jun.'19 = 259.3	Aug.'18 = 279.7	
Industrial Production in Manufacturing (2012 =100)*	Aug.'19 = 105.2		Jul.'19 = 104.7	Jun.'19 = 105.1	Aug.'18 = 105.7	
Hourly earnings index, chemical & allied products (1992 = 100)	Aug.'19 = 185.6		Jul.'19 = 185.2	Jun.'19 = 185.3	Aug.'18 = 182.8	
Productivity index, chemicals & allied products (1992 = 100)	Aug.'19 = 95.7		Jul.'19 = 94.7	Jun.'19 = 95.1	Aug.'18 = 98.7	

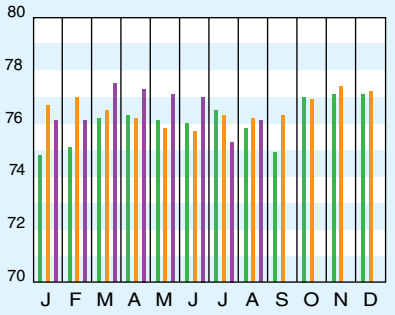
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top; the most recent available) for July 2019 decreased from the previous month's value. The decline is the fifth within the last six months. Decreases in the Equipment and Buildings subindices offset slight increases in the Engineering & Supervision and Construction Labor subindices to account for the lower value for the overall CEPCI in July. The preliminary July CEPCI value is 0.4% lower than the corresponding value from a year ago. It is the first time since October 2016 that the current CEPCI value has been lower than the year-ago value. Meanwhile, the CBI numbers for August 2019 (middle) show small increases in the CPI output index and the CPI operating rate.